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Productivity Growth and Technical Change in India's Energy Intensive Industries: A Survey

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A Survey

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Abstract

We survey the available literature on productivity growth and technical change in six energy intensive industries in India covering the period 1947-1998. The motivation for the survey is to assess the magnitude of the autonomous energy efficiency improvement (AEEI) parameter for India's industrial sector. The industries covered are aluminium (non-ferrous metals), cement, fertilisers, glass and glass products, iron and steel, and paper and paper products. We also survey studies relating to productivity growth in aggregate manufacturing in order to gain a broader perspective.

The survey reveals productivity growth to be an active area of research in India, both at the aggregate level as well as at the industry level. Over time increasingly complex functional forms and sophisticated econometric techniques have been employed for analysis of productivity growth. Also, efforts have been made to arrive at more accurate measurement of factor inputs, particularly for capital. The survey also indicates wide inter- and intra-industry variation in estimates of partial and total factor productivity due to differences in methodology, levels of aggregation, sources of data, time periods of analysis, and reporting procedures.

In view of these differences, it is difficult to make a definitive judgement about the nature and magnitude of productivity growth in energy intensive industries in India. The overall impression is that of positive though imperceptible growth in productivity over time. The policy implication is that little reliance can be placed on the AEEI factor as the moderating influence on growth of energy demand. This also points to the need for estimating productivity growth using uniform methodology, common data source and the same time period for all industries.

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1. Introduction

Models of integrated assessment have played an important role in climate policy analysis in recent years. These models are being progressively refined and elaborated in order to better reflect complex international dynamics of climate policy. Models which were constructed with aggregate representation of the global economy are being disaggregated. As part of this process, it has been felt necessary to study in greater detail the evolution of energy use in developing countries. The projected growth of income and population in these countries indicate large potential increases in energy use. Further, as part of the historical process of structural change, as share of manufacturing in gross domestic product increases, overall energy intensity in the economy will tend to go up. This tendency can get counteracted by investment in energy efficiency and by energy conservation measures. In addition, an important factor which can counteract this tendency is the autonomous energy efficiency improvement (AEEI) parameter. This parameter indirectly reflects overall productivity growth in the economy. While productivity growth is important for all sectors of the economy, it is crucial for the manufacturing sector where policy induced development has mainly been directed in the last half century.

The objective of the present study is to survey the available literature on productivity growth and technical change in six energy intensive industries in India. These industries are : Aluminium, Cement, Fertilisers, Glass and glass products, Iron and Steel, and Paper and Paper products. We also survey studies relating to productivity growth in aggregate manufacturing in order to gain a broader perspective.

In terms of broad organisation, this survey will list (i) what studies, if any, have been conducted on productivity growth in respect of industries mentioned above, (ii) the context, nature and scope of such work, and (iii) data and methodology used.

The survey covers studies relating to the period 1947-1998. Within this broad period different studies relate to different sub-periods depending on the objective of the study and due to data availability. This survey is an analytical-descriptive account of the existing studies on productivity and technical change. It is not a critical review of individual studies from the point of view of either the scope of work, methodology or data used or results derived. Also, this survey does not attempt an exposition of general or econometric methodology of measurement of productivity or technical change.[1] Therefore, references on this aspect have not been mentioned except when they have a direct bearing on our work. Our purpose is to bring together the variety of results on productivity growth which have been arrived at with alternative assumptions, methodological frameworks, or sources of data used. We then ask if a consensus is possible on the most likely rates of productivity growth in the light of this variety observed.

Many studies on productivity growth and technical change also deal with elasticities of substitution and economies of scale and technical efficiency related issues. In this survey we deal with productivity growth and technical change aspects only to keep the survey focused. Similarly, studies in the nature of energy audits, dealing with energy use over time, have been left out, even

[1] On these aspects see Krishna (1987), Goldar (1992), (1997).

though they have an indirect bearing on the issue. Many of these studies, however, are listed in the bibliography.

The plan of this survey is as follows. This section serves as an introduction. Section 2 provides a brief rationale for studying productivity growth. Section 3 is devoted to the meaning and measurement of productivity growth. Section 4 lists different approaches to the measurement of productivity growth. Section 5 has a brief perspective on energy intensive industries in India. Section 6 contains an account of the studies on productivity growth. Section 7 summarises broad conclusions emerging from this account.

2. Rationale for Studying Productivity Growth

The need for studying productivity growth arises due to the intimate link between productivity growth and economic growth. Economic growth has implications for resource use in general and for use of energy in particular. Energy use in turn has implications for climate change, which countries will not be able to ignore for long.

2.1 Productivity Growth and Economic Growth

Productivity growth is the basis of efficient economic growth. Economic growth has been defined as the process of a sustained increase in the production of goods and services with the aim of making available a progressively diversified basket of consumption goods to population.

Scarcity of resources, which includes physical, financial and human resources, has been recognised as a limiting factor on the process of economic growth. While output expansion based on increased use of resources is feasible, it is not sustainable. Therefore, efficiency or productivity of resources becomes a critical factor in economic growth. These terms, which will be defined more precisely in the following section, indicate ability to obtain a given amount of good or service by using a lesser amount of input. Productivity growth, therefore, is critical for ensuring sustained increase in the production of goods and services.

Economic growth has traditionally been associated with industrialisation. At least that is what makes the diversity in the basket of consumption goods and services possible, when trading possibilities are limited. But industrialisation in the initial stages has the effect of making resource scarcities more acute, making it all the more necessary that available resources are utilised more productively.

Role of productivity growth in the process of economic growth became clear when in the 1950's it was found that accumulation of productive factors (capital and labour) could explain only a fraction of actual expansion of output. Empirical work on the American economy by Tinbergen (1942), Schmookler (1952), Fabricant (1954), Abramovitz (1956), Kendrick (1957), Solow (1957) and Denison (1962) showed that between 80 to 90 percent of observed increase in output per head could not be explained by increase in capital per head and was attributed to productivity growth. Further, Terleckyi (1974), Scherer (1982, 1987) and Griliches (1984) showed that technological advancement was a major source of productivity improvement for the American industry.[2]

While productivity growth and technological change affect the use of all factors, it is important to single out energy for a separate treatment. Energy is essential for economic growth and rapid increases in economic activity associated with accelerating economic growth lead to large increases in energy demand. As economic growth progresses, and the economy moves away from agricultural to industrial modes of production, the energy intensity, energy use per unit of GDP, first increases and then declines. The growth of energy use over time is traced by a dome shaped curve. India, like many other developing countries is in the rising phase of this curve. This phenomenon has the effect of draining away of resources from other `directly productive' sectors of the economy. It also has implications for environmental pollution.

Productivity growth in the manufacturing sector in general and in the energy intensive industries in particular has the effect of moderating the growth of energy demand. The degree of this moderation of course depends on magnitude and the nature of technological change. If technological change is neutral, in the sense that it affects all inputs equally, the degree of moderation will depend on the overall growth of technological progress. If it has an energy saving bias, there will be significant degree of moderation. If on the other hand, technological change has an energy using bias, the economy is likely to experience a rapid increase in energy demand, requiring explicit policy initiatives.

Implications of productivity growth for climate change analysis are straightforward. Carbon emissions are primarily a result of burning of fossil fuels. In the absence of sizeable resources being available for investment in energy efficiency, and in the absence of viable possibilities of energy conservation, reliance will have to be placed on productivity growth and technological for reducing energy use.

3. Meaning and Measurement of Productivity Growth

Productivity is a relationship between production and the means of production. Or, more formally a relation of proportionality between the output of a good or service and inputs which are used to generate that output. This relationship is articulated through the given technology of production.

3.1 Productivity Growth and Technological Change

Productivity growth is crucially affected by technological change. Their relationship is so close that the two terms are often used interchangeably. Productivity is a wider concept. Even though a crucial one, technological change is only one of the many factors which affect productivity growth. Other being social, cultural, educational, organisational and managerial factors. Better management of workers and machines and appropriate incentive structures can increase production and/or reduce costs. But these are different from technological change.

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2 This point is more fully discussed in Goldar(1986).

It is not easy or straightforward to disentangle the effects of technological change from social and cultural factors. One simple way to conceptualise the differences is in the following way suggested by Spence (1984). If changes concern primarily people then they may reasonably be considered as being *social* in nature. On the other hand, if they appear to be fundamentally about material products and related processes then they can be more easily viewed as *technological*.

3.2 Technology and Technological Change

At this stage it is appropriate to ask what does technological change mean. A prior question is what is technology? Unfortunately, there is no simple answer to this question. Marjit and Singh (1992) have explored various aspects of this question. We confine ourselves to one directly relevant for our study. In the standard neo-classical economic model technology refers to a collection of techniques, or ways of specifying how much of various outputs can be produced using given quantities of various inputs. In most textbook situations this is simplified as a single output production function which specifies the maximum quantity of output predicable from given quantities of labour and capital. Technology is then the production function. It is generally represented graphically with the help of level curves or isoquants. Technological progress in this simple framework is a shift upwards of the production function, or shift downwards of the representative isoquant.

An alternative way is to look at cost functions which relate levels of cost of production to level of output and to factor prices. In many situations cost functions are easier to characterise production functions. The data for cost functions is more easily available. Given input prices, one can view technological improvement as a downward shift of the cost function.

Technology has two aspects, ‘embodied’ or ‘disembodied’. The former is identified with ‘hardware’ and consists of tools, machinery, equipment and vehicles, which together make up the category of capital goods. Disembodied technology is identified with ‘software’ and encompasses the knowledge and skills required for the use, maintenance, repairs, production, adaptation and innovation of capital goods. These are often called the ‘know-how and the know-why of processes and products’.

Technological change does not affect all factors equally. When it does, it is considered neutral technical change. Otherwise, it may have a specific factor using or factor saving bias.

The terms technological change and technical change are used interchangeably in the literature under review, both being indicators of a shift in the production function. It would have been useful to reserve the latter term for indicating change in techniques or processes. The terms technological progress and technical progress are synonymous with technological change and technical change respectively, all change being considered as being for the better.

3.3 Production Function and Productivity Growth

As indicated above, the notion of a production function is central to the meaning of technology. It is consequently crucial for the measurement of productivity. A production function is a technological relationship which specifies the maximum level of output of a good which can be obtained from a given level of one or several inputs.

In its general form a two input production function can be written as

(1) $V_t = f(K_t, L_t)$

Where,
V_t = level of net output (value added).
K_t = capital input (or service of factor capital)
L_t = labour input
t = time

3.4 Partial or Single Factor Productivity

The partial or single factor productivity (PP) of labour or capital is indicated by the ratio V/L, or V/K i.e. output per unit, or the average product of the factor concerned. The productivity defined this way is merely the inverse of factor intensity. An increase in this ratio, other things remaining the same, implies an increased efficiency of input use, whereby, the same level of output can be produced by a smaller quantity of given input.

However, when other things cannot be assumed to be the same, the interpretation of these output factor ratios as indicators of productivity becomes problematic. For example, an increase in labour productivity may only reflect capital deepening - a rise in the K/L ratio. In such cases it becomes necessary to compute total factor productivity.

3.5 Total Factor Productivity

Total factor productivity (TFP) extends the concept of single factor productivity such as output per unit labour or capital to more than one factor. Thus TFP is the ratio of gross output to a weighted combination of inputs. For the case of production function shown above, TFP at time t would be given by:

(2) $$A_t = \frac{V_t}{g(\alpha K_t, \beta L_t)}$$

Where
A_t : Index of TFP at time t.
g : the aggregation procedure implicit in the specific production function adopted.
α, β are appropriate weights.

Different functional forms of the production functions imply different aggregation procedures or weighting schemes for combining factor inputs.

3.6 Total Productivity (TP) versus Total Factor Productivity (TFP)

At this stage, choice exists in regards to the specification of output as value added (V) as in equation (1) above or gross value of output (Y). In the latter case, material and energy inputs are explicitly accounted for in both the left and the right hand sides in the production function. This would give rise to the following general functional form which in recent years has come to be known as KLEM type production function.

$$Y_t = g(K_t, L_t, E_t, M_t, t)$$

Where,
Y_t = level of gross output per unit of time,
K_t = capital input (or service of factor capital)
L_t = labour input
E_t = input of energy,
M_t = material inputs.
t = time

The choice between one form of the other depends on what one believes to be the correct measure of output. It also depends on whether one believes the production function to be separable in factor and material inputs or not.

The above functional forms give rise to alternative concepts of productivity. One can define the productivity measure associated with the value added (V) production function as total factor productivity (TFP) and that associated with gross output (Y) production function as total productivity (TP)[3].

In the survey which follows it will be seen that the majority of studies have been conducted using production functions with value added as output and with K and L as inputs. It is only recently that studies on production functions in India have been using gross output and K, L, E and M as inputs.

4. Approaches to the Measurement of Productivity Growth

There are three principal approaches to measurement of productivity growth. These are: (i) The index number approach, (ii) parametric approach and (iii) non-parametric approach.

In the present survey we focus primarily on studies which have estimated productivity growth using the first approach. Wherever appropriate, the results from the estimation of cost and production functions have been mentioned in support of as alternative explanations to the

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[3] This usage may not be universal. It was recently suggested by Rao (1996).

results of the first approach. The non-parametric approach which is based on linear programming models of relative efficiency is not reviewed here.

4.1 Index Number Approach

In this approach the observed growth in output is sought to be explained in terms of growth in factor inputs. The unexplained part or the residual is attributed to growth in productivity of factors. It consists in assuming a certain functional form for the producers' production function and then deriving an index number formula that is consistent (exact) with the assumed functional form. Preferred functional forms are the flexible ones. These indices differ from each other on the basis of underlying production function or the aggregation scheme assumed. Following are some of the most commonly used indexes.

Kendrick Index

Kendrick's index of total factor productivity for the case of value added as output, and two inputs can be written as

$$A_t = \frac{V_t}{(r_0 K_t + w_0 L_t)} \tag{3}$$

Where,
A_t is the value of index in a given year,
V_t is the value of gross output,
w_0 and r_0 denote the factor rewards of labour and capital respectively in the base year.

The index measures average productivity of an arithmetic combination of labour and capital with base year period factor prices. It assumes a linear and a homogeneous production function of degree one. Besides constant returns to scale and neutral technical progress, it assumes an infinite elasticity of substitutability between labour and capital. The index can be generalised to allow for more than two factors.

If a sufficiently long time series for this index can be constructed, then a trend rate of growth can be estimated econometrically.

From the time series of Kendrick index yearly series (g_t) can be formed by writing growth between successive years as

$$g^K_{t+1} = (A_{t+1} - A_t) / A_t$$

The growth rates thus obtained can be appropriately averaged for sub-periods.

Solow Index

Solow's measure of productivity growth for two input case is given by (4)

$$g_{t+1}^{S} = \left[\frac{V_{t+1} - V_t}{V_t}\right] - \left[\alpha \frac{L_{t+1} - L_t}{L_t} + \beta \frac{K_{t+1} - K_t}{K_t}\right]$$

Where,

V_j = measure of output,

α, β are shares of labour (L) and capital (K) in output.

This measure is based on the general neo-classical production function. It assumes constant returns to scale, Hicks-neutral technical change, competitive equilibrium and factor rewards being determined by marginal products.

Under these conditions, the growth of total factor productivity is the difference between the growth of value added and the rate of growth of total factor inputs. The latter is in the form of a Divisia index number i.e. a weighted combination of the growth rates, the weights being the respective shares.

If we assumed specific Cobb-Douglas production function, with unit elasticity of output (unlike in the general functional form above) and took base year factor shares as weights, we would get Domar's geometric index of TFPG.

Assuming $A_1 = 1$, a time series of Solow index of productivity (A_t) can be formed from the formula:

$A_{t+1}= A_t * (1+g^S_{t+1})$

Translog Index

Translog measure of TFPG is given by:

$$(5) \qquad g_{t+1}^{T} = ln\left[\frac{Y_{t+1}}{Y_t}\right] - \left[\left(\frac{s_{t+1}^{L} + s_t^{L}}{2}\right) * ln\left(\frac{L_{t+1}}{L_t}\right) + \left(\frac{s_{t+1}^{K} + s_t^{K}}{2}\right) * ln\left(\frac{K_{t+1}}{K_t}\right)\right]$$

This expresses TFP as the difference between growth rate of output and weighted average of growth rates of labour and capital input. This is equivalent to Tornquist's discrete approximation to continuous Divisia index. The index is based on the translog function which describes the relationship between output and inputs and also between the aggregate and its components. The homogeneous translog functional form is flexible in the sense that it can provide a second order approximation to an arbitrary twice continuously differentiable linear homogeneous function. This functional form helps overcome the problem which arises with the Solow index where discrete set of data on prices and quantities need to be used in a continuous function. This index also imposes fewer a priori restrictions on the underlying production technology. The index can be generalised for more than two inputs.

Like in the previous case, from year to year changes in productivity growth one can construct a time series of the translog index as follows:

$$A_{t+1}= A_t * (1+g^T_{t+1})$$

4.2 Parametric Approach

Parametric approach consists in econometric estimation of production functions to infer contributions of different factors and of an autonomous increase in production over time, independent of inputs. This latter increase, which is a shift over time in the production function, can be more properly identified as technological progress. It is one of the factors underlying productivity growth. An alternative to estimation of production functions is estimation of cost functions using results from the duality theory. Below we give some commonly used specifications of production functions.

Cobb-Douglas Specification

(6) $$V = A_0 e^{\lambda t} L^{\alpha} K^{\beta}$$

Where, V, L, K and t refer to value added, labour, capital and time. α and β give factor shares respectively for labour and capital. A_0 describes initial conditions. Technological change takes place at a constant rate λ. It is assumed to be disembodied and Hicks-neutral, so that when there is a shift in the production function, K/L ratio remains unchanged at constant prices.

In log-linear form this function can be written as

(7) $$\log V = a + \alpha \log L + \beta \log K + \lambda t$$

The estimated value of λ provides a measure of technological progress, which is often identified with total factor productivity growth.

Constant Elasticity of Substitution (CES) Specification

(8) $$V = A_0 e^{\lambda t}\left(\delta L^{-\rho} + (1-\delta)K^{-\rho}\right)^{-\frac{\upsilon}{\rho}}$$

Where λ is the efficiency parameter, δ the distribution parameter, ρ the substitution parameter and υ is the scale parameter. The elasticity of substitution $\sigma = 1/(1+\rho)$ varies between 0 and $\propto$. Technical change is Hicks neutral and disembodied. The value of λ (a measure of technical progress) can be estimated using a non-linear estimation procedure, or by using the following Taylor-series linear approximation to the CES function:

(9) $$\ln V = \ln A_0 + \lambda\, t + \upsilon\, \delta \ln L + \upsilon\, (1-\delta) \ln K - (1/2)\, \rho\upsilon\delta\, (1-\delta)\, (\ln L - \ln K)^2$$

This function can be estimated by OLS.

Transcendental Logarithmic (TL) Specification

(10) $$\log V = \alpha_0 + \alpha_L (\log L) + \alpha_K (\log K) + \alpha_t + \frac{1}{2}\beta_{LL} (\log L)^2 + \frac{1}{2}\beta_{KK} (\log K)^2 + \beta_{LK} (\log L)(\log K) + \beta_{Lt} (\log L)\, t + \beta_{Kt} (\log K)\, t + \frac{1}{2}\beta_{tt} t^2$$

where α's and β's are the parameters of the production function.

The rate of technical progress or total factor productivity growth is given by

(11) $$\frac{\partial \log V}{\partial t} = \alpha_t + \beta_{tt}\, t + \beta_{Lt} (\log L) + \beta_{Kt} (\log K)$$

Where,
α_t is the rate of autonomous total factor productivity growth.
β_{tt} is the rate of change of TFPG, and
β_{Lt}, β_{Kt} define the bias in TFPG.

If both β_{Lt} and β_{Kt} are zero, then the TFPG is Hicks-neutral type. If β_{Lt} is positive then the share of labour increases with time and there is labour using bias. Similarly, a positive β_{Kt} will show a capital using bias.

4.3 Direct Estimation of Cost Functions

Due to results of the duality theory, one may estimate a cost function instead of production function to calculate technical progress. In its general form a four factor cost function can be written as

(12) $C = C(P_L, P_K, P_E, P_M, Q, t)$

Specific forms of cost functions corresponding to each of the above functional forms can be derived. We give below the translog cost function which has many desirable properties sought out by researchers and which has been used most commonly in recent years.

Translog Cost Function

$$\log C = \alpha + \sum_i \beta_i \log p_i + \frac{1}{2}\sum_i \sum_j \log p_i \log p_j + \beta_Q \log Q$$

$$+\frac{1}{2}\beta_{QQ}(\log Q)^2 + \beta_{Qt}\log Q \log t + \beta_t \log t + \frac{1}{2}\beta_{tt}(\log t)^2 \tag{13}$$

$$+\sum_i \beta_{Qi}\log Q \log p_j + \sum_i \beta_{ti}\log t \log p_i$$

Using Shepherd's lemma one can estimate demands for individual factors and shares in total cost of individual factors as follows:

$$\frac{\partial \log C}{\partial \log p_i} = \frac{x_i\, p_i}{C} = S_i = \beta_i + \sum_j \beta_{ij}\log p_j + \beta_{Qi}\log Q + \beta_{ti}\log t \tag{14}$$

Rate of technical progress (λ_t) is given by

$$\lambda(t) = \frac{\partial \log C}{\partial t} = \frac{1}{t}\left(\beta_t + \beta_{tt}\log t + \beta_{Qt}\log Q + \sum_j \beta_{ti}\log p_i\right) \tag{15}$$

Technical progress has a factor i using bias if $\beta_{ti} > 0$. It is neutral with respect to factor i if $\beta_{ti} = 0$ and it is factor i saving if β_{ti} is < 0.

5. Energy Intensive Industries in India

After independence industrialisation occupied a dominating place in India’s development strategy. The industrial policy resolution of 1948 provided the basic contours of official policy in this regard. Depending on their perceived importance in the overall scheme of things, industries were put into different categories. The six industries under review were considered of vital importance. Thus, iron and steel, which was perceived to be essential to the development of all industries, was put in the category, the development of which henceforth would be the exclusive responsibility of the state. Aluminium, along with other non-ferrous metals, cement, fertilisers, paper and newsprint were considered of such basic importance that Central Government would need to plan and regulate them. Only glass was left to the category which was open to private enterprise. Subsequently, industrial policy resolution of 1956 shifted the emphasis to heavy and capital goods industries, where ‘machines would make machines which would in turn make consumer goods’. There was a reclassification of industries in the light of new emphasis, but the six industries continued to occupy a central place in the policy makers mind.

Looking back on the development experience in the last 50 years, one can see the important role these industries have played. Apart from providing the critically needed capital goods and intermediate goods for other industries, these industries have been a source of both direct and indirect employment for a sizeable part of the population. At the same time, on the negative side, the development of these industries has become a source of concern because they consume a large part of energy in the manufacturing sector. As a result of this they have become an important source of green house gas emissions. They have been identified as polluting industries even otherwise.

The manufacturing sector in India accounted for 21 percent of the gross value added and between 45 to 50 percent of the total energy consumption in 1993-94. The six energy industries mentioned above accounted for 14 percent of the value added in the manufacturing sector and of 29 percent of energy consumed in value terms. The Table 5.1 below, which lists individual shares of 6 energy intensive industries in gross value added and fuels consumed for the year 1993-94, places them in the perspective of the overall manufacturing sector.

Table 5.1 : Gross Value Added and Fuel Shares of Energy Intensive Industries in India.

Industry and ISIC codes	Share in Gross Value added %	Share in fuels consumed %	Energy Intensity (Fuels consumed / GVA)
Aluminium (335)	0.90	1.93	0.69
Cement (324, 327)	1.62	7.76	1.54
Fertiliser (301)	3.25	5.58	0.55
Glass (321)	0.38	0.95	0.81
Iron and Steel (330)	6.53	9.95	0.49
Paper (280+281+282+283)	1.50	3.19	0.68
Aggregate of 6 industries	14.17	29.35	0.32
Aggregate Manufacturing	100.00	100.00	0.32

Source: ASI, Summary Results for Factory Sector, 1993-94.

Memo:
In 1993-94 Gross Value Added for the manufacturing sector as a whole was Rs. 10,48.8 billion, and the total value of fuels consumed was Rs. 337.247 billion.
GDP in 1993-94 was Rs. 7,231 billion.

Below we present a brief account of development of these six energy intensive industries in India.

5.1 Aluminium

Aluminium is a versatile non-ferrous metal with favourable weight, strength and electrical properties. It finds applications in a wide range of manufacturing and serves as an essential input to the power industry, one of the priority sectors in the Indian economy. The importance of aluminium is heightened by the fact that India does not have an adequate resource base for copper, while there are abundant reserves of bauxite which is the basic raw material for producing aluminium.

Apart from the power sector which consumes over 50% of aluminium production, the households sector takes up 19% where it finds application as a cheap substitute for brass and steel. The transport sector consumes 11 %. Buildings and construction, packaging and use in the manufacture of other machine and equipment take up 6% each. Currently, per capita consumption is very low compared to industrialised countries. However, with rising population and incomes demand is expected to increase significantly. The industry is an important source of employment. Over 30,000 people are directly employed in production of aluminium from the bauxite to smelting stage. Another 210,000 are employed in the downstream activities of manufacture of aluminium products.[4]

Production of aluminium in India started in 1943 when Indian Aluminium Co. set up a smelting plant in Kerala. In 1950, annual production capacity was a mere 5 thousand tonnes. at 80% capacity utilisation. By 1960, installed capacity had increased more than threefold and capacity utilisation was at 100%. During the sixties, the industry expanded rapidly, with the result that in 1970 the capacity had increased to 185 thousand tonnes at still high capacity utilisation (91%). In this initial phase rapid growth of industry was facilitated by favourable conditions on the supply as well as demand side. The industry was not yet subject to controls except in the matter of capacity licensing.

Sector specific policies and inadequate power supply adversely affected the production environment in the 1970s. As a result, although capacity further expanded capacity utilisation decreased to only around 50% in 1980. In 1990-91, the situation improved and capacity had increased to 610 thousand tonnes with 73.67 % of the capacity utilised. The public sector has played an important part in the development of the aluminium industry. Currently, almost 50% of production capacity is in the public sector.

5.2 Cement

The cement industry is an important index of economic development. As a major input to all kinds of construction activities, cement is used in almost every sector of the economy. In agriculture, it is needed for dam and canal building, in transportation for railway, road, bridge construction, and in other sectors for offices, commercial complexes, factories and residential houses. Cement production is very energy intensive holding the biggest share in fuels consumed among the energy intensive sectors under consideration. The industry employs over 200,000 persons directly and indirectly.

At the time of independence India was poorly developed in major facilities. Transforming the country into an industrial economy required essentially the development of cement and steel industry. Being a bulky commodity, cement could not be easily imported from abroad. The

4 Kalra and Radhakrishnan (1987)

country had a good resource base and it was felt necessary that the industry be developed locally.

Production of cement started in India in a small way in 1879. However, its systematic development started in 1914 when Indian Cement Company set up a plant in Porbandar in Gujarat. From then on, production increased continuously. In the 1950s capacity expanded at a rate of 12% per annum with capacity utilisation at around 85%. Yet, the following two decades saw a decline in the growth rates. In 1980-81, capacity stood at 27 million tonnes and production at 18.1 million tonnes, implying rates of growth of 5% and 2.65% in the previous decade. Capacity utilisation came down to a mere 67%.

The slowdown in capacity creation was attributable to disincentives provided by the scheme of comprehensive controls on production, prices and distribution which applied to the cement industry. Under-utilisation of capacity was due to shortage of coal, irregular power supply, inadequate availability of wagons for movement and periodically also demand recession. The industry was partially decontrolled in 1982 and then fully in 1989. The decontrol resulted in progressive increase in production. By 1991-92, capacity stood at 65 million tonnes with an increased capacity utilisation of 82%. This implied an impressive growth rates of 9.18% per annum during the previous decade. The targeted level of capacity creation for the year 1996-97 is 90 million tonnes and it is expected that its utilisation will further increase to 84%.

Along with the increase in production there has been an upgradation of technology. Progressively the proportion of energy efficient dry process plants has gone up and now stands at over 70%compared to mere 30% a decade ago. The advent of mini cement plants with 200 tonnes per day capacity had ensured regional dispersion. The newer cement plants compare well with the plants in the world in terms of productivity and cost and the country, because of a favourable resource base and locational advantage vis a vis the neighbouring countries is likely to emerge as a net exporter of cement.

5.3 Fertiliser

Chemical fertilisers have played a critical role in the success of India's green revolution. Their use coupled with high yielding varieties of seeds and irrigation water helped increase foodgrain production from 50 million tonnes in 1950-51 to over 200 million tonnes currently. The current levels of per capita food grains consumption for a large segment are still very low. This combined with the rising population indicated that India will need to produce over 225 million tonnes of foodgrains by the year 2000. This in turn will call forth increasing levels of consumption and production of fertilisers.

India has a large and diversified fertiliser sector-the fourth largest in the world. The industry has shown impressive growth since independence. State support in the form of subsidies contributed to the growth in a substantial way. In 1950, the total capacity was a mere 16 thousand nutrient tonnes of Nitrogen and of 20 thousand tonnes of Phosphate. By 1960 these figures had risen to 162 thousand tonnes and 96 thousand tonnes respectively. There was rapid progress in the 1960's and 1970s. With the result that in 1980 the production capacity stood at 4358 thousand tonnes for Nitrogen and 1333 thousand tonnes for Phosphates. By 1990 these figures had further risen to 8146 thousand tonnes of Nitrogen and 2751 of Phosphates.

Along with this expansion, the industry has undergone significant technological transformation. Increasing amount of additional capacity has been created using natural gas as the feedstock in place of naphtha, fuel oil, and coal which were the preferred feedstocks in the past. Also, there has been an impressive increase in capacity utilisation. In 1980, average capacity utilisation was 53% for nitrogen plants and 65% for phosphatic plants. Currently the capacity utilisation is 90% and 92% for the two sets of plants.

5.4 Glass

Production of glass in India began over a hundred years ago. At the time of independence annual production of glass was a mere 30 thousand tonnes. At present, the industry produces over 1 Mt of various types of glass including hollow-ware and press-ware flat glass, sheet wired and figured glass. Glass has wide spread applications in construction, transport vehicles, and household goods. In many of these uses there are no substitute materials. Glass competes with plastics and aluminium for many packaging applications. Because glass is an inert material and does not react to chemicals, glass contains are very important for industries like pharmaceuticals, dairy products, processed food, cosmetics, beverages, infusion products, distilleries, and breweries. Glass bangles are used as an ornament by a large number of women in India.

The glass industry is labour intensive and provides both direct (manufacture of glass) as well as indirect (mining and transport of raw materials) employment

Though the share of glass in total gross value added and in total fuels consumed is low in relation to other industries, its energy consumption per unit of output is rather high.

5.5 Iron and Steel

India's steel industry started in 1907 with the establishment of Tata Iron and Steel Company (TISCO). By the time of independence another integrated steel plant Indian Iron and Steel Co. (IISCO) had been added to India's steel making capacity. After independence the government of India restricted creation of integrated steel plants (ISP) to the public sector. During the 1950's, the private companies, TISCO and IISCO, were allowed to expand and three greenfield were established by the public sector. With the commissioning of another steel plant in the late 1960's and take-over of IISCO in 1972, the public sector became the dominant steel manufacturer in the country. In 1973, the government formed a holding company Steel Authority of India Limited (SAIL). Construction of a sixth public ISP started in 1981.

The restrictive licensing policy by the government which put the ISP's under the domain of the public sector did not bar installation of small electric arc furnace (EAF) steel plants (mini-steel plants) and re-rolling plants by the private sector. By mid-80's there were 160 mini-steel plants and over 1000 re-rolling plants operating in India. The combined capacity of public and private sector was 14.4 million tonnes of crude steel. The actual output was 9.93 million tonnes implying around 69% capacity utilisation. Currently, India has a production capacity of around

25.43 Mt and an actual production of 23.22 Mt in terms of saleable steel.

5.6 Paper

India's paper industry, apart from its widespread use in packaging industry, is vital to the countries literacy, education and social development plans.

The Paper industry in India started in the 19^{th} century and enhanced substantially after 1924 when the technology of production from bamboo was established. At the beginning of the first five year plan, the installed capacity of paper and paper board was only 1.37 lakh tonnes and the production was 1.32 lakh tonnes, giving a capacity utilisation of more than 96%. By the end of the sixth five year plan in 1984-85, the capacity had increased to 23.5 million tonnes and production to 13.51 million tonnes, giving a capacity utilisation of only 48.3 %.

The main reasons for low capacity utilisation have been non-availability of adequate quantities of cellulosic materials, breakdowns of old machinery with the small units, uncertain supply of coal and power. By 1990-91 the capacity had risen to 32.84 million tonnes and production to 19.56 million tonnes implying 60 % capacity utilisation. The target capacity and target production for 1996-97 is 35 and 29 million tonnes respectively, implying 82% capacity utilisation.

6. Studies on Productivity Growth and Technological Change in India

6.1 Background

At the start of the planning process in India a great deal of emphasis was placed on increasing the rate of savings and investment. This was in conformity with the development doctrine of the 1950's which emphasised capital formation and industrialisation. In the following two decades savings rate more than doubled. Also, a firm basis was laid for a diversified industrial structure. However, the growth rate of the economy continued to stagnate at low levels. Consequently, doubts were raised about the efficiency of resource use. Also it was debated whether the observed increase in labour productivity reflected increased efficiency, or was merely the result of capital deepening. In the sixties, soon after the conclusion of the second five year plan, Indian economists began in earnest to investigate the growth of factor productivity. Empirical work done on the American economy, referred to earlier , was an important source of inspiration and provided a methodological stepping stone. The prevailing spirit of enquiry was best summed up by Brahmananda's rhetorical subtitle to his book `Productivity in the Indian Economy: Rising Inputs for Falling Outputs'.

In the following we report on some of this literature. The number of studies on productivity growth and technological change in India is vast by now. Indian researchers have studied the subject in a variety of contexts and with differing motives. Also, the methodological framework and the level of detail vary widely across studies. In what follows, our prime concern is with energy intensive industries. We have reported on studies on productivity growth in aggregate manufacturing to provide the overall perspective. These studies also provide the bench mark against which to judge the individual sector studies. The field has been competently surveyed earlier by Krishna (1987) and Goldar (1992). In the following we have drawn at places from these two studies.

6.2 Studies on Aggregate Manufacturing

Studies undertaken in the early sixties did not indicate a significant contribution of total factor productivity growth to output growth. Reddy and Rao (1962) for the period 1946-57 and Singh (1966) for 1951-63 found no definite upward trend in total productivity. There was a fall in the productivity of capital and the observed increase in labour productivity was attributed to increasing capital intensity. Similar conclusions were reached by Sivamaggi et al. (1968) for the period 1951-61 and Rajkrishna and Mehta (1968) for 1946-64. The latter in fact showed that total productivity had declined. These studies were followed in later years by several with better methodological tools and with longer series of data.

In 1975, Banerji studied productivity growth for large scale manufacturing industry. With his work began special attention to measurement of capital. His estimates marked an improvement on those of earlier authors in respect of arriving at the bench mark estimate for the base year and also in respect of deflation of capital series. About the same time, Hashim and Dadi refined the measurement of capital further in their study of organised manufacturing sector. Mehta's main focus in 1980 was on productivity growth in 27 large scale industries, but he also reported aggregate results for the census sector for an overlapping period of his study. Goldar (1986) studied the aggregates covering CMI industries for the years 1951-65 and large scale industries for the years 1959-79. He brought further improvement to estimates of capital input by paying special attention the benchmark estimates and by incorporating important assumption of discarding of assets over time.

Ahluwalia's work (1985 and 1991) is the most detailed and comprehensive treatment of productivity growth for the registered manufacturing sector in India. In terms of methodology her work differed from those of others in an important respect. While earlier authors had deflated their output series at the aggregate level, she deflated series for different groups by their corresponding WPI's and then added these series to arrive at the aggregate value series. The major focus of her study was linking productivity growth to industrial growth and in particular to the timing of the turnaround in the Indian economy. Balakrishnan and Pushpangdan (1994) bring out the difference which the adoption of double deflation procedure in place of single deflation procedure makes to the productivity growth series. They have in particular disputed Ahluwalia's timing of the turnaround of industrial growth. In 1996, Rao examined rigorously the issues raised by Balakrishnan and Pushpangdan regarding the double deflation procedure and indicated that it could in fact lead to the possibility of negative real valued added. He also presented estimates arrived at under alternative assumptions about the separability of material and non-material inputs. Pradhan and Barik (1998) suggest that production functions for the aggregate manufacturing in India cannot be assumed to be separable in material and non-material inputs on the basis of statistical tests. Mitra et al. (1998) in a recent study have examined the impact of development and availability of infrastructure on productivity growth and technical efficiency for 17 manufacturing industries in India at the state level.

In what follows we briefly review these studies to bring out reasons for difference in estimates. It is not practicable to do a pair wise comparison for all studies. We, therefore, focus on studies according to the chronological sequence of time periods, and compare them successively. In what follows, unless stated otherwise, all studies have used data from Census of Manufacturing Industries (CMI) and/or Annual Survey of Industries (ASI). Basically CMI data had been used till the year 1958 and ASI data for years beyond. Either gross or net value added has been used as a measure of output. Total number of employees or workers represented labour input. Wages were approximated by earnings per employee (workers). Book value of gross fixed assets, subject to author specific adjustments, have been used to represent capital. Nominal values of output and inputs were converted to real magnitudes using appropriate wholesale price indices as deflators.

Table 6.2.1: Partial and Total Factor Productivity Growth: Aggregate Manufacturing

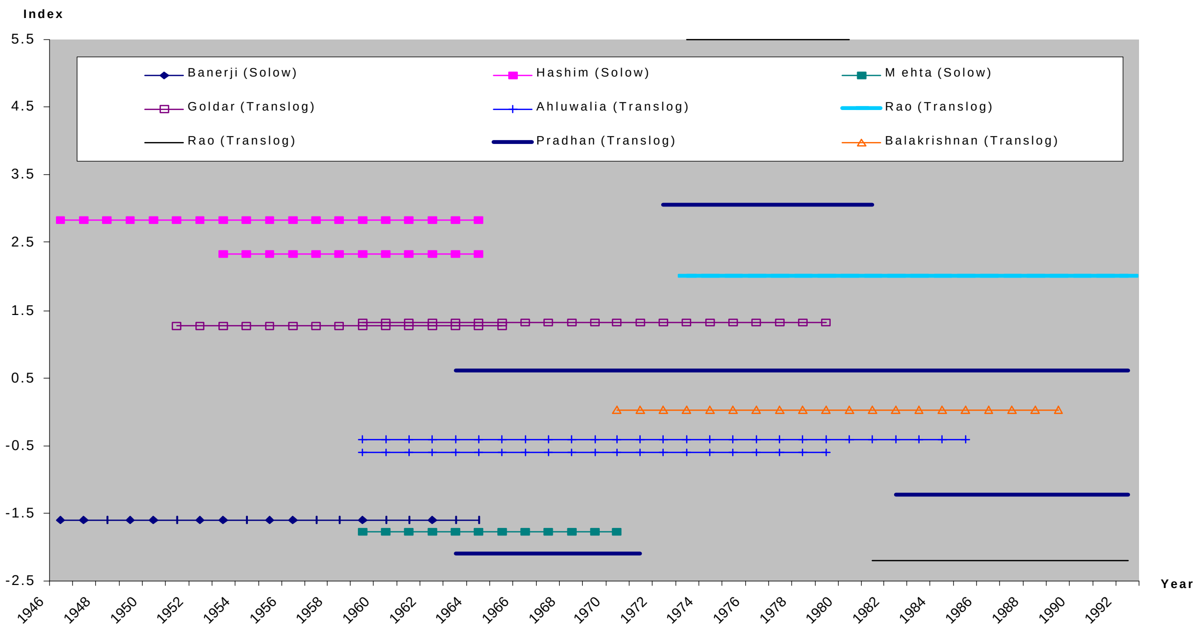
Author	Period	Capital Productivity	Labour Productivity	K/L Ratio	TFPG	Measure
Banerji (1975)	1946-64	- 6.20	3.33	9.60	- 1.60	S*
Hashim (1973)	1946-64	1.70	3.70	0.26	2.82	S**
	1953-64	0.00	4.10	4.07	2.33	S**
Mehta (1980)	1959-70	- 4.68	5.86	11.0	- 1.77	S*
Goldar (1986)	1951-65	- 1.14	3.83	5.38	1.27	T*
	1959-79	--	--	--	1.31	T*
Ahluwalia (1985, 1991)	1959-79	--	--	--	- 0.60	T***
	1959-85	-2.50	2.20	4.90	- 0.40	T**
Balakrishnan (1994)	1970-89	--	--	--	0.20	T**
Rao (1996)	1973-92	--	--	--	2.00	T**
	1973-80	--	--	--	5.50	T**
	1981-92	--	--	--	- 2.20	T**
Pradhan (1998)	1963-92	--	--	--	0.61#	T**
	1963-71				- 2.09#	T**
	1972-81				3.06#	T**
	1982-92				- 1.23#	T**

Notes: All numbers are growth rates per cent per annum
S indicates Solow Index, T indicates Translog index.
# indicates total productivity measure,
* indicates compound annual growth rates, ** Indicates semi-log trend rate of growth,
*** indicates simple average of year to year growth rates, -- indicates not reported or not available.

Representative estimates of partial and total factor productivity by different authors have been brought together in Table 6.2.1. These cover different sub-periods during the years 1946 to 1992. Further, TFPG growth rates are shown in Figure 6.2.1. The horizontal bars show the average of growth rates applied to the time span for which the study was done. The bars are marked with different authors names and codes for productivity indices. This presentation has the tendency to hide the inter-temporal movements of indices but has the advantage of dramatising the differences in growth rates by different authors.

The estimates show wide variation across authors and over time. They range from -1.77 to 5.5 per cent per annum. The differences can be attributed to differences in (i) definitions and measurement of variables, particularly of capital, (ii) choice of deflators, (iii) sources of data, (iv) time periods considered, (v) choice of index, (vi) methods of calculating, averaging and reporting growth rates.

Figure 6.2.1 Total Factor Productivity Growth: Comparative Estimates



Some of the more specific reasons for these differences are discussed below:

For the earlier years 1946-64, the differences between the estimates of Banerji (-1.61% p.a.) and Hashim and Dadi (2.82% p.a.) are by and large attributable to differences in the measurement of the capital stock. Goldar's estimate (1.2% p.a.) for the overlapping though later period, 1951-65, falls between these two estimates possibly because of assumption of discarding of capital assets which placed his estimates in between the two. Mehta's estimate (-1.77% p.a.) for the later period 1959-70 is closer to Banerji's, the difference arising partly because of the time span and partly due to coverage. The difference in Goldar's estimate (1.3% p.a.) for 1959-79 and Ahluwalia's (-0.6% p.a.) for the same period can be attributed to two main reasons: (i) assumption of discarding of assets which Goldar makes but Ahluwalia does not, and (ii) difference in deflation procedure. For the longer period 1959-85, the lower absolute magnitude of the negative growth rate according to Ahluwalia is indicative of the turnaround in the industrial and productivity growth rates. But it could also be due to differences in reporting procedure. The fact of turnaround is disputed by others on the basis of deflation procedures used. Balakrishnan and Pushpangdan's numbers (not reported) are indicative of this. The reported estimate in the table agrees with Ahluwalia because it is arrived at by the same procedure as Ahluwalia. Rao's numbers show results based on different deflation and aggregation procedure and are contrary to Ahluwalia's hypothesis. Pradhan's estimates are not strictly comparable with others because they are based on gross value of output and not on gross value added and not surprisingly give results which are contrary to other estimates. The estimates of Mitra et. al. though extremely important are in a different framework and therefore are not included for a comparison.

In the light of the above what can we say about the most likely rates of total factor productivity growth? If we concentrate on estimates which are methodologically transparent and sound, and also, if we focus on the long run disregarding small sub-periods, the plausible range of estimates is likely to be -1 to +1.

6.3 Sectoral Studies

In addition to the studies at the aggregate manufacturing level reviewed above, several authors have studied partial and total productivity growth in individual industries either singly or in groups. Energy intensive industries studied by us have featured in them. The motivation for undertaking these studies has varied.

Banerji extended his study of productivity growth and technical change reported earlier to 5 selected industries. These included Paper. For Mehta, the main objective was to study technological change in 27 large scale manufacturing industries in India. These included Cement, Glass and Glassware, Iron and Steel, and Paper and Paper Board. His results on productivity growth in the Census sector were incidental and actually a post-script to his main objective. Goldar wanted to explain inter-industrial variations in productivity growth in the light of chosen variables. For this he took a sample of 37 ASI industries at the 3-digit level. These included Aluminium (Non-Ferrous Metals), Cement, Glass and Glass Products, Iron and Steel basic industries, Pulp, Paper and Paperboard, CSO studied wages and productivity in 20 major industrial groups. These included Aluminium (non-ferrous metals), Cement, Iron and Steel and Pulp, Paper and Paper Board. Ahluwalia, complements her study of productivity growth in the aggregate manufacturing by estimation for the 63 industrial sub-groups at the 3-digit level. These included all the six energy intensive industries under review. In her 1985 study Ahluwalia had reported productivity growth in Paper and Paper Products at the two digit level. The methodology followed by these authors has already been outline above.

We outline below methodology adopted by others who have studied groups of industries with varying motives.

Arora (1987) analysed the effect of R&D expenditure on productivity growth in selected industries at the 3-digit level. These included Fertilisers, Glass and Glass Products, Cement and Gypsum and Paper and Paper Products. She used translog measure of TFPG and reported un-weighted averages of year to year growth rates. The period of her study is 1973-81. Her choice of variables and methodology is broadly similar to that of Goldar though she does not assume discarding of capital assets.

Dabir-Alai (1987) studied TFPG for eighteen large scale (Census sector) manufacturing industries at the two digit level for the years 1973-78. His study included Paper and Paper Products. The coverage is same as that in Ahluwalia (1985). He used Kendrick and Solow indices to measure TFPG and reported unweighted averages of year to year growth rates. The choice of variables and methodology is again similar to Goldar except that he used a different procedure for arriving at his capital series. He used CSO's input-output table for 1973/74 and

Planning Commission’s input-output table for 1979/80 to compile a break up of the fixed assets used by the manufacturing establishments making up the Census sector in India.

In contrast with the above, many authors have estimated productivity growth for individual industries or sectors because of their specific interest in them. The distinguishing points of their methodology will be described below within each sector when their estimates are discussed.

In regard to reporting on these studies below, our remarks made in the context of aggregate manufacturing above hold. Therefore, in what follow, unless explicitly mentioned, it should be assumed that (i) the authors have used CMI or/and ASI as source of data (ii) traditional decomposition analysis has been used to measure productivity growth (iii) either gross or net value added has been used as a measure of output (iv) wholesale price indices of appropriate commodities / groups have been used as deflators, (v) book value of gross fixed assets, directly or using perpetual inventory accumulation method, subject to author specific adjustments, have been used to represent capital (vi) the index number of machinery and construction, and variants thereof, have been used for deflating the capital series (vii) labour input has been represented by total number of employees or workers (viii) wages were approximated by earnings per employee (workers).

6.3.1 Aluminium

Aluminium which accounted for slightly less than 1% of the gross value added of the manufacturing sector in 1993, had a share of around 2% in fuels consumed. In the literature on total factor productivity growth there are no separate studies on Aluminium. It is included in the Non-ferrous metals category where it accounts for over 65 per cent of the value of output. For this category itself only a few studies have been done. These are indicated below along with the time periods covered:

Goldar (1986) for the period 1960-70, CSO (1981) for 1960-77 and for different sub-periods, Ahluwalia (1986) for 1959-85. These estimates have been arrived at using the standard growth accounting approach with gross value added as a measure of output. In contrast, Pradhan and Barik (1998) used gross output as a measure of output and adopted a four input framework for their estimates for the period 1963-71.

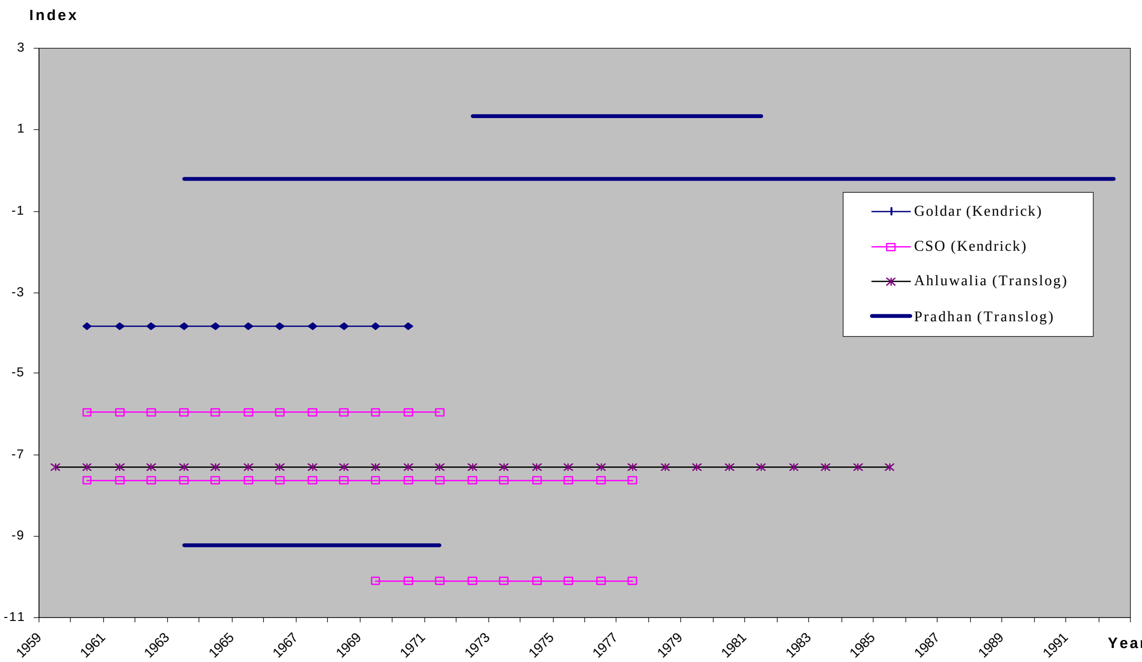
The estimates are shown in the Table 6.3.1 and illustrated in Figure 6.3.1 below.

Table 6.3.1: Partial and Total Factor Productivity Growth: Aluminium@

Author	Period	Capital Productivity	Labour Productivity	K/L Ratio	TFPG	Measure
Goldar (1986)	1960-70	- 5.50	0.37	6.21	- 3.83	K*
CSO (1981)	1960-77	- 9.17	- 1.53	7.64	- 7.62	K*
	1960-71	- 7.58	- 1.26	6.32	- 5.96	K*
	1969-77	-11.55	- 1.94	9.61	-10.10	K*
Ahluwalia (1986)	1959-85	- 9.30	- 3.00	6.90	- 7.30	T**
Pradhan (1998)	1963-92	--	--	--	- 0.20#	T**
	1963-71	--	--	--	- 9.21#	T**
	1972-81	--	--	--	1.33#	T**
	1982-92	--	--	--	- 2.30#	T**

Notes: All numbers are growth rates per cent per annum
@ Estimates refer to non-ferrous metals
# indicates total productivity measure.
K indicates Kendrick index; T indicates Translog index
* indicates compound annual growth rates; ** Indicates semi-log trend rate of growth
-- indicates not reported or not available.

Figure 6.3.1 Total Factor Productivity Growth: Aluminium



Goldar's and CSO's estimates are in broad agreement with each other. The differences are within the acceptable range and arise because of the difference in the length of the period considered and also because of estimation procedure for capital stock. As suggested earlier Goldar's estimates of capital incorporate the assumption of discarding of capital assets. His lower relative estimates of growth of capital stock, reflected in growth of capital labour ratios, give rise to comparatively higher estimates of capital productivity and of total factor productivity. CSO's estimates for different sub-periods hint at worsening production environment in the seventies compared to that in the sixties. Ahluwalia's estimates too are in agreement as far as the direction is concerned. Differences in numerical magnitudes can be attributed to methodological differences and to the lengths of the time periods considered. The positive productivity growth indicated by Pradhan for the sub-period 1972-81 can be the result of the output variable having been differently defined.

In an alternative framework, Kokrady (1992) provided confirmation to the state of little productivity growth above. Using ASI data he estimated a modified translog cost function and reported negligible technical progress. Also, whatever little technical progress was there was found to be labour saving, capital using and neutral with respect to energy inputs.

Overall, the estimates show that in the non-ferrous metals industry, of which Aluminium is a part, there was little or no productivity growth. Most estimates are in agreement as far as the direction of the change is concerned. Barring methodological differences, they are in agreement broadly on the magnitude of change also . It is reasonable to have the judgement that over all there was negligible or negative productivity growth in this sector.

6.3.2 Cement

Productivity growth in the cement industry has been studied more extensively and also more systematically compared to that in the Aluminium industry which was reviewed above. There are studies where the focus is on the cement industry per se and those where the industry has been studied as part of a group of industries.

Table 6.3.2: Partial and Total Factor Productivity Growth: Cement

Author	Period	Capital Productivity	Labour Productivity	K/L Ratio	TFPG	Measure
Gupta (1973)	1946-65	- 0.55	2.51	3.06	-1.06#	K
Mahopatra (1970)	1949-64	--	--	--	1.80#	S**
Sawhney (1967)	1950-61	1.50	7.30	5.80	1.90	K**
Sinha (1970)	1950-63	1.91	4.70	2.79	1.70	K**
Arya (1981)	1951-70	- 6.00	2.60	9.15	0.25	S**
Mehta (1980)	1953-64	- 5.60	-1.60	4.00	- 5.40	S**
					- 5.50	K**
Acharya (1978)	1960-71	--	--	--	0.25	
Goldar (1986)	1960-70	- 0.37	2.66	3.05	0.50	K*
CSO (1981)	1960-77	1.86	1.12	- 0.74	1.62	K*
	1960-71	- 1.44	2.37	3.81	- 0.30	K*
	1969-77	4.54	- 0.51	- 5.05	2.99	K*
Ahluwalia (1991)	1959-85	- 1.40	1.30	2.70	- 0.50	T**
Arora (1987)	1973-81	- 1.66	2.29	5.19	- 1.96	T***
Pradhan (1998)	1963-92	--	--	--	1.71#	T*
	1963-71	--	--	--	- 5.51#	T*
	1972-81	--	--	--	0.01#	T*
	1982-92	--	--	--	- 6.79#	T*

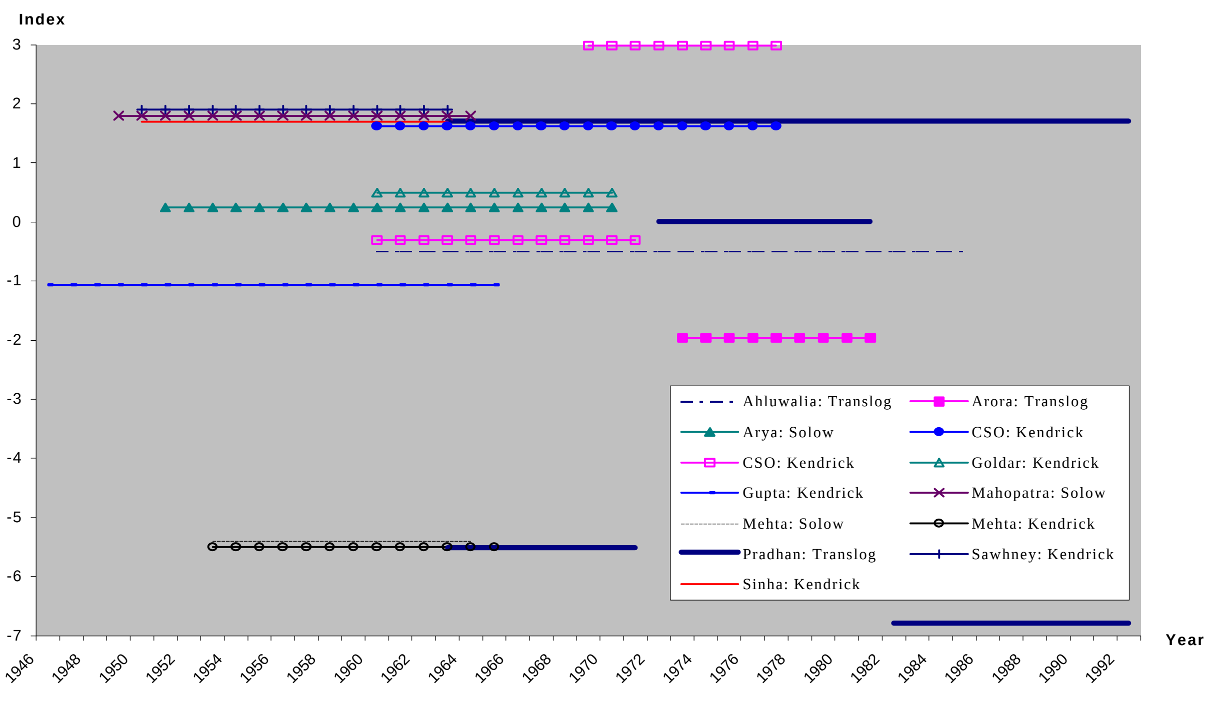
Notes: All numbers are growth rates per cent per annum.
K indicates Kendrick index; T indicates Translog index.
* indicates compound annual growth rates; ** indicates semi-log trend rate of growth.
*** indicates simple average; -- indicates not reported or not available.
# indicates total productivity measure.

The growth rates of capital and labour productivity and of total factor productivity for these studies are shown in Table 6.3.2 along with growth in capital-labour ratios. The TFPG estimates are also shown in Figure 6.3.2.

Gupta (1973) used gross value of output (instead of GVA) as a measure of output. And in a three input (capital, labour and raw materials) framework used modified Kendrick index to estimate TFPG. Capital input was taken as the reported book value of fixed assets. He used values of output and inputs at current prices. His estimates therefore are not directly comparable with those of others who use GVA as a measure of output. One problems with this kind of measure is that when input price index rises faster than the output price index, partial and total factor productivity will tend to be underestimated.

Mahopatra (1970) used gross ex-factory value of products and by-products as a measure of output. He used the capital series of Sinha and Sawhney (see below). Departing from the standard practice, he used a lag structure and related output of period t_1 to capital stock of period t_0. The estimate of TFPG for a sub-period within Gupta's period of study contrasts sharply in spite of the output variable being the same. This can be due to variables being used in real versus nominal terms, the incorporation of a lag structure and the use of different indices.

Figure 6.3.2 Total Factor Productivity Growth: Cement



Sawhney (1967) and Sinha and Sawhney (1970) arrived at broadly similar rates of TFPG because of similarity of methods and coverage. They took GVA at constant prices as a measure of output. Labour input was measured by number of persons employed. Capital series was arrived at by perpetual inventory method, by first estimating the value of gross fixed capital for a base year and then adding annual increments deflated by the price index for capital goods to the capital stock. The results agree broadly with those of Mahopatra in spite of the definitional differences for output, use of different indices and of lag structure used by the latter.

Mehta's estimates of large negative TFPG can be the result of specific adjustment procedure for reconciliation of CMI/ASI data, and of choice of measure for reporting. His series exhibit fluctuations, and therefore, estimating equations for trend rates of growth are characterised by low R-square values. Simple averages of year to year growth rates increase the estimate to a more plausible range.

Arya (1981) used a net measure of output and capital. He deflated his output series by index number of ex-works cement prices fixed by the government. Since these prices would generally be lower than the free market prices, the value of output would be underestimated. The series on net fixed capital was deflated by index number of capital goods prices. This could possibly lead to relative over-estimation of capital series. Not surprisingly, therefore, he reported negligible TFPG.

Acharya and Nair (1978) represented output in physical terms, justifying it on the ground that Cement was a homogenous commodity. Capital stock which was arrived at by the perpetual inventory accumulation method was further adjusted to arrive at capital service flow variable. They arrived at factor shares from econometric estimates of production function and reported TFPG of 0.25% per annum through decomposition using Solow measure. The estimate compares with that of Arya even though it is for a sub-period and is also based on different methodology.

Goldar's (1986) estimates for 1960-70 are consistent with that of CSO (1981) for the comparable period except for the difference caused by his assumption of discarding of assets. The assumption would lead to lower relative estimates of capital stock and consequently higher estimates of capital and also of total factor productivity. They would also compare well with Ahluwalia's estimates for the longer period, the difference again being attributable to the reasons above.

Arora's large negative estimates are attributable to her averaging procedure. Because of a short time series she used unweighted averages of the year to year growth rates. Finally, Pradhan's estimates are comparable with those of Gupta and Mahopatra because of similar definition of output.

As we can see estimates fall in a wide range. A set of general reasons for these differences was given at the end of Section 6.2. In this section we mentioned many specific reason which rendered many estimates non-comparable. In spite of these it appears that the most likely long run rate of growth of total factor productivity for the years 1945 to 1985 can be restricted to the range -0.5 to 0.5 per cent per annum.

6.3.3 Fertiliser

Surprisingly, in spite of its importance to the Indian economy, productivity in the fertiliser sector has not been studied extensively. The available studies are by Gupta (1982) for the period

1969-76, Ahluwalia (1991) for 1959-85, Arora (1987) for 1973-81, and Bansal (1997) for 1986-94.

Gupta's aim was to analyse relative productivity performance of the public and private sector enterprises. The analysis was conducted with primary plant level data. According to her, productivity of capital and labour declined both in public and private sector units. The rate of decline was much higher for the private sector. This pattern was true for total factor productivity too where measured by the Kendrick index it declined at the rate of 2.42 per cent per annum in the public sector and at the rate of 8.53 per cent per annum in the private sector. This would imply that total factor productivity should have decreased in the fertiliser sector as a whole.

Ahluwalia's estimates for the much longer period showed a much smaller decline in capital productivity and actually a reasonable increase in labour productivity, and also in total factor productivity. Arora's estimates broadly agree with that of Ahluwalia because of similarity of methodology and sources of data. The small difference can be attributed to difference in time period considered also because of deflation and averaging procedures.

Bansal compared the productivity performance of fertiliser units in the public and the private sectors for the years 1986-94. She used data obtained from annual reports of companies for the private sector units and from `Public Enterprises Survey' for the public sector units. Her estimates, even though not statistically significant, tend broadly to confirm the analysis of Gupta in regard to relative performance of public and private units. This could be because of similarity of methodological framework, even though the source of data was different.

These estimates are brought together in Table 6.3.3 and also shown in Figure 6.3.3 below:

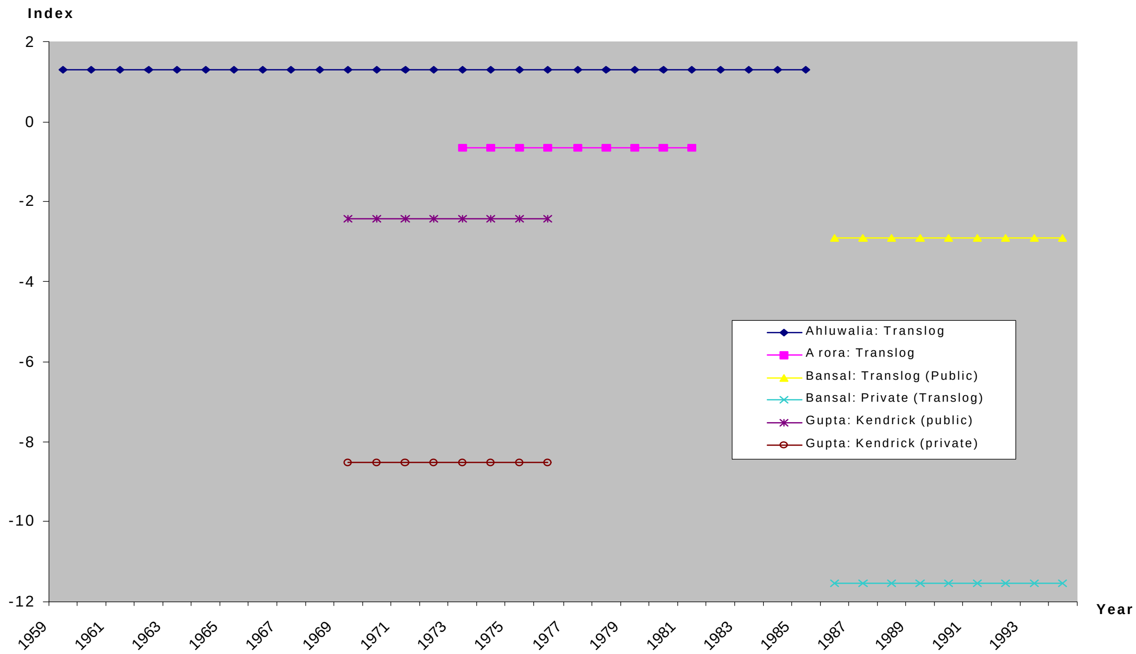
Table 6.3.3: Partial and Total Factor Productivity Growth: Fertiliser

Author	Period	Capital Productivity	Labour Productivity	K/L Ratio	TFPG	Measure
Gupta (1982)	1969-76					
	Public	-5.62	-3.32	2.30	-2.42	K**
	Private	-9.36	-6.20	3.16	-8.53	K**
Ahluwalia (1991)	1959-85	-1.00	6.30	7.50	1.30	T**
Arora (1987)	1973-81	-0.62	5.41	5.50	-0.65	T***
Bansal (1997)	1986-94					
	Public	-3.10	-2.20	0.90	-2.91	T**
	Private	-13.4	-4.80	8.60	-11.53	T**

Notes: All numbers are growth rates per cent per annum.
K indicates Kendrick index; T indicates Translog index.
** indicates semi-log trend rate of growth; *** indicates simple average.

The table above shows how the choice of source of data makes a difference to the productivity growth estimates. Compare estimates of Ahluwalia and Arora with those of Gupta and Bansal. Productivity of capital is decreasing in all estimates. However, it decreases massively in the estimates of Gupta and Bansal. One possibility is overestimation of capital because of the source of data. Also, their estimates show labour productivity to be declining, while Ahluwalia and Arora show it to be rising. This is reflected in the rates of capital deepening and also finally in the rates of TFPG. The vastly different conclusions reached by the two studies can thus be traced to different sources of data, size of the sample and time period of study.

Figure 6.3.3 Total Factor Productivity Growth: Fertiliser



Overall, the estimates of Ahluwalia and Arora seems more plausible, the small difference between their own estimates being attributed to the difference in periods covered, also due to growth reporting procedure.

6.3.4 Glass

Estimates of productivity growth in glass industry have been provided by authors as shown in Table 6.3.4. The methodological details of estimation by these authors have already been noted in the previous three sections.

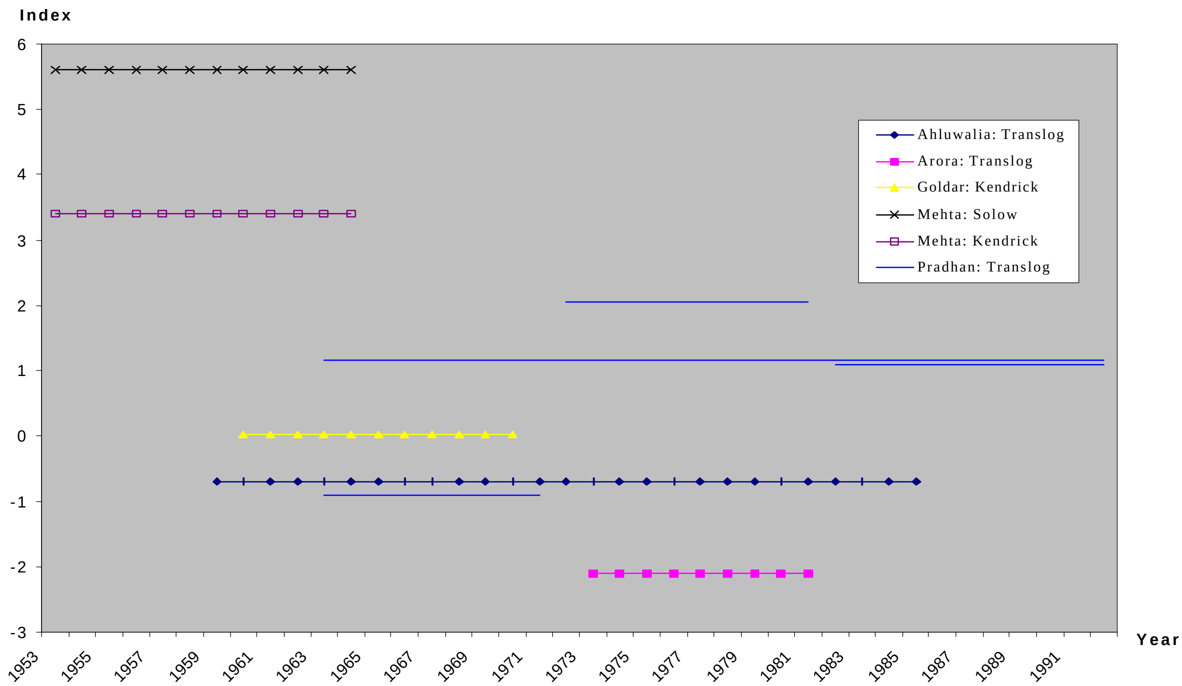
Mehta reported significant TFPG and supported it with a production function estimate which indicated technical progress at the rate of 14.5 per cent per annum. Goldar's period of study partly overlaps with Mehta's, but he found little growth in productivity. A possible clue to this wide divergence can be found in the capital labour ratios. It is clear that either the industry segments they were considering were different or Mehta either overestimated output or underestimated growth of capital stock. It should be remembered at this stage that because of assumption of capital discarding Goldar's estimates have corrected for overestimation of capital stocks. If we take into account Ahluwalia's figures, the most likely estimates of TFPG appear to be near zero. Arora's estimates are for a smaller period and also are simple averages. Pradhan's estimates are not directly comparable, as pointed out earlier.

Table 6.3.4: Partial and Total Factor Productivity Growth: Glass

Author	Period	Capital Productivity	Labour Productivity	K/L Ratio	TFPG	Measure
Mehta (1980)	1953-64	3.3	6.1	2.8	5.6	S**
					3.40	K**
Goldar (1986)	1960-70	- 3.64	4.90	8.87	0.03	K*
Ahluwalia (1991)	1959-85	- 4.2	1.9	6.4	-0.7	T**
Arora (1987)	1973-81	- 2.5	0.62	3.12	-2.11	T***
Pradhan (1998)	1963-92	--	--	--	1.16#	T**
	1963-71	--	--	--	-0.90#	T**
	1972-81	--	--	--	2.05#	T**
	1982-92	--	--	--	1.09#	T**

Notes: All numbers are growth rates per cent per annum.
# indicates estimates of total productivity.
S indicates Solow index; K indicates Kendrick index, T indicates Translog index.
* indicates compound annual growth rates; ** indicates semi-log trend rate of growth.
*** indicates simple average; -- indicates not reported or not available.

Figure 6.3.4 Total Factor Productivity Growth: Glass



6.3.5 Iron and Steel

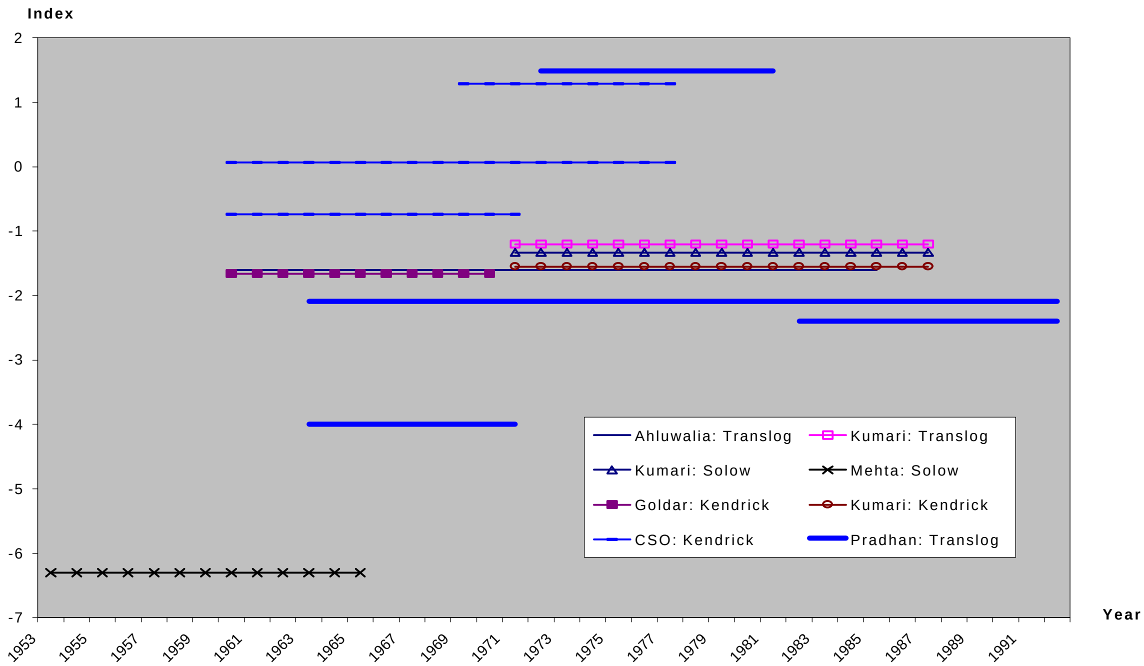
Estimates for productivity growth in the iron and steel industry are presented in Table 6.3.5 and Figure 6.3.5. Except for Kumari, the methodological details of the above authors have been discussed earlier. Kumari analysed productivity trends at the group level in the public sector enterprises for 11 groups of manufacturing industries. Steel comprised one of the 11 groups analysed by her. She used data drawn from Public Enterprises Survey. In other respects she followed the same procedures.

Table 6.3.5: Partial and Total Factor Productivity Growth: Iron and Steel

Author	Period	Capital Productivity	Labour Productivity	K/L Ratio	TFPG	Measure
Mehta (1985)	1953-64	-22.8	-5.2	16.9	-6.3	S**
					- 22.9	K**
Goldar (1986)	1960-70	-3.23	0.96	4.19	-1.66	K*
Ahluwalia (1991)	1959-85	- 2.8	0.10	2.90	-1.60	T**
CSO (1981)	1960-77	-0.81	0.89	1.70	0.07	K*
	1960-71	-2.74	1.48	4.22	-0.74	K*
	1969-77	2.07	0.00	-2.07	1.29	K*
Kumari (1993)	1971-87	-2.54	-0.74	1.80	-1.2	T**
					-1.33	S**
					-1.55	K**
Pradhan (1998)	1963-92				- 2.09#	T**
	1963-71				- 4.00#	T**
	1972-81				1.49#	T**
	1982-92				- 2.40#	T**

Notes: All numbers are growth rates per cent per annum.
S indicates Solow index; K indicates Kendrick index; T indicates Translog index.
* indicates compound annual growth rates. ** indicates semi-log trend rate of growth.
*** indicates simple average. -- indicates not reported or not available.
# indicates total productivity measure.

Figure 6.3.5 Total Factor Productivity Growth: Iron and Steel



Mehta reported total factor productivity growth, measured by Solow index, at the rate of -6.3 per cent per annum. Measured by Kendrick index the decline is at the whopping 22.9% per annum. These estimates can result only because of adjustments in the data series introduced by the author by his attempt to make CMI data compatible with ASI data. His estimates of production function, which showed technical progress taking place at the rate of 8.8 per cent per annum, make his estimation more difficult to understand.

Goldar’s estimate of -1.66 percent per annum appears to be in the reasonable range. This estimate is supported by CSO’s estimates for the comparable period 1960-71, in terms of direction of change, though numerical magnitudes differ slightly. Differences in results across different sub-periods in the CSO study can be due to fluctuations in the productivity growth series. Ahluwalia’s estimates for the much longer period are in accord with that of Goldar and also those of CSO. Kumari’s estimates even though they are based on data drawn from a different source do not contradict the negative growth rates. Total factor productivity measured by translog index declined at the rate of 1.2 per cent per annum. Her estimates by Kendrick and Solow index show broadly similar results. Further her estimates of Cobb-Douglas production function showed technical progress was taking place at the rate of 3.3 per cent per annum. This indicated that the resource use was much worse than indicated by TFPG estimates. Finally, Pradhan’s estimates, in spite of difference in methodology show negative growth rates in ranges broadly comparable to those of other authors.

The most likely growth rate of total factor productivity in the Iron and Steel industry appears to fall in the range of -1.60% to 0.07% per annum.

6.3.6 Paper

Productivity growth in the Paper industry has been studied relatively more extensively. Estimates by various authors are brought together in Table 6.3.6. and Figure 6.3.6.

Banerji reported negative but near zero growth of total factor productivity which as he said could be the result of mixed movements over time. His estimates of production function led Banerji to believe that capital deepening in the paper industry had been accompanied by some sort of technical progress. His results on technical progress go contrary to a contemporary study by Berthwal (1971) who found absence of technical progress in paper industry on the basis of time series estimation for the period 1949-64. Banerji attributed the variance in results to difference in the period of study as well as the data used.

Sinha and Sawhney’s reported estimate of TFPG at 0.9 per cent per annum for 1950-63. This was a sub-period within Banerji's period of study. Mark the difference in the growth of K/L ratio. In spite of this the difference in productivity growth estimates can still be considered within the acceptable range and is possible additionally because of difference in length of the period and in choice of index.

Mehta’s estimates differ widely from those of others. This along with the results if his production function estimation which showed technical progress at the rate of 15.9 per cent per annum, point to the possibility of unstated differences in the definition of variables. Mark again the large growth rate of capital-labour ratio.

Goldar’s estimate for a slightly later though partially overlapping period pointed in the opposite direction from that of Mehta’s. It is within the reasonable range when compared with that of CSO for the period 1960-71. If one compares Goldar's figures for growth of capital labour ratios with that of Mehta and of CSO, a possible reason for difference in estimates appears to be differences in measurement of capital. CSO's estimates for the longer period (1960-77) and a later sub-period (1969-77) indicate slackening of growth rates. Though the basic growth rates remain comparable with that of Goldar. Ahluwalia's estimate of low negative growth for a much longer period may be the result of slackening which had set in the later part of sixties and which is also reflected in the estimates of Dabir-Allai and also of Arora. It needs to be pointed here that Dabir-Allai's estimates is at the 2-digit level and hence implies a much larger variable aggregate being studied. It compares well with estimate of 0.5 per cent per annum in Ahluwalia (1985) which is comparable in terms of level of aggregation and also of reporting procedure.[5] Arora's estimate would be less extreme if a more appropriate reporting procedure was used. Parhi's positive growth rates for a period when they appeared to be turning negative otherwise, need to be discounted because of extreme values of growth of capital-labour ratios and of capital productivity. Pradhan's estimates though done in a different methodological framework do not contradict the broad tendencies indicated by the previous three authors.

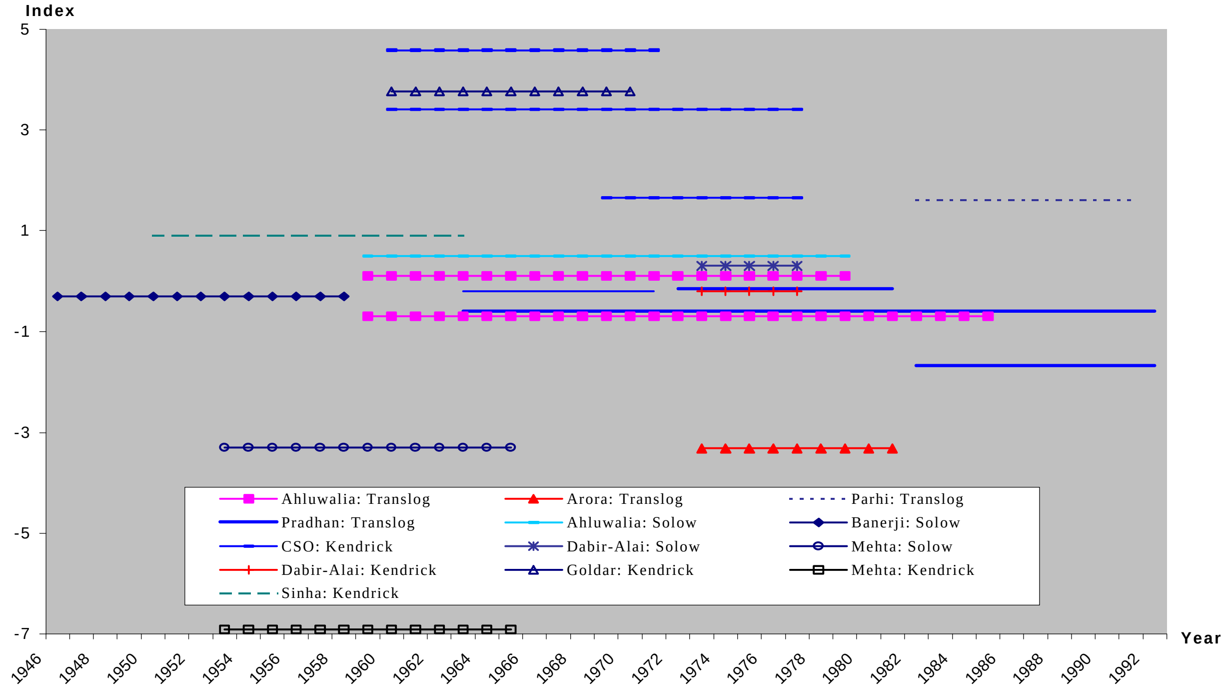
Table 6.3.6: Partial and Total Factor Productivity Growth: Paper

Author	Period	Capital Productivity	Labour Productivity	K/L Ratio	TFPG	Measure
Banerji	1946-64	-0.4	6.00	6.4	-0. 30	S*
Sinha	1950-63	1.61	3.90	2.29	0.9	K**
Mehta	1953-64	-6.9	0.9	7.8	-3.3	S*
					- 6.90	K**
Goldar	1960-70	2.61	6.16	3.55	3.76	K*
CSO	1960-77	3.11	3.78	0.67	3.41	K*
	1960-71	3.71	6.11	2.40	4.58	K*
	1969-77	2.21	0.26	-1.95	1.65	K*
Ahluwalia	1959-79	--	--	--	0.1	T***
		--	--	--	0.5	S***
	1959-85	-2.0	1.5	3.6	-0.7	T**
Dabir-Allai	1973-78	-0.8	0.6	1.4	0.30	S***
					- 0.20	K***
Arora	1973-81	-3.98	-0.62	3.36	-3.32	T***
Parhi	1982-91	-18.88	3.6	22.48	1.61	T**
Pradhan	1963-92	--	--	--	-0.59	T*
	1963-71	--	--	--	-0.2	T*
	1972-81	--	--	--	-0.15	T*
	1982-92	--	--	--	-1.67	T*

Notes: All numbers are growth rates per cent per annum.
K indicates Kendrick index. T indicates Translog index.
* indicates compound annual growth rates. ** indicates semi-log trend rate of growth.
*** indicates simple average. -- indicates not reported or not available.
# indicates total productivity measure.

5 Ahluwalia (1985) reports two additional estimates like in the case of aggregate manufacturing. See previous footnote. These are (i) $Translog_a$ = 0.5 per cent per annum, and (ii) $Translog_b$ = 1.2 per cent per annum. These show like in the previous case wide variation which differences in the measurement of capital can make.

Figure 6.3.6 Total Factor Productivity Growth: Paper



Like in the previous cases, paper industry throws up a wide range of estimates which differ from each other due to a variety of reason. It is difficult to form an overall judgement. But it is possible that, as indicated by Goldar and CSO, productivity in the decade 1960-70 could have increased at the rate of close to 3 per cent per annum. However, this finding needs to be reconciled with the longer period estimates of Ahluwalia.

7. Conclusions

Our survey indicates that productivity growth continues to be an active area of research in India, both at the aggregate level as well as at the disaggregated industry level. Over time increasingly complex functional forms and sophisticated econometric techniques have been employed for analysis of productivity growth. Also, efforts have been made to arrive at more accurate measurement of factor inputs. This is particularly true of capital.

There is wide variation in results across studies in respect of indices of partial and total factor productivity, both at the aggregate as well as industry level. The estimates of productivity growth and technological change by different authors are not strictly comparable because of differences in methodology, levels of aggregation, sources of data and time periods of analysis.

In view of the above, it is difficult to make an unambiguous judgement about the nature and magnitude of technical progress or productivity change in energy intensive industries in India. However, if we were to take the results reported by different authors as indicative numbers, they would indicate a positive though imperceptible growth in productivity over time. There is a clear need for arriving at estimates of productivity growth and technological change in all six energy intensive industries using uniform methodology, common data source and same time period.

References

Abramovitz, M., Resource and Output Trends in the United States since 1870. *American Economic Association*, Papers, May 1956.

Achyara, S. and Nair, N.K., Empirical issues in total productivity measurement, an experiment with cement industry in India. *Productivity*, 1978, **19**:3.

Ahluwalia, I.J., *Productivity and growth in Indian manufacturing*. Oxford University Press, Delhi, 1991.

Ahluwalia, I.J., TFPG in Manufacturing Industry. *Economic and Political Weekly*, 22 October 1994, p. 2836.

Apte, P.C., Substitution among energy and non-energy inputs in selected Indian manufacturing industries, an econometric analysis. *Indian Economic Journal*, 1983, **31**, pp. 71-90.

Arya, I.C., Technology and productivity of cement industry in India - A case study of fifteen cement companies, *Arthavijnana*, 1983, **25**:3, pp. 259-276.

Arya, I.C., On measuring technological change in cement industry in India. *Arthavijnana*, 1981, **23**:2, pp. 167-179.

Anon, A study of productivity in the iron and steel industry in India. *Manpower*, 1996, **5**:3, p. 110.

Arora, A., The transfer and technological know how to developing countries: licensing, tacit knowledge and the acquisition of technological capability. PhD thesis, Stanford University, 1991.

Arora, P., Productivity and research and development: a study of some selected industries. M.Phil. Thesis, Delhi School of Economics, University of Delhi, 1987.

Atkinson, A.B. and Stiglitz, J.E., A new view of technological change. *Economic Journal*, 1995, **79**, September, pp. 46-49.

Balakrishnan, P. and Pushpangdan K., What do we know about productivity growth in Indian industry? *Economic and Political Weekly*, 1998, **33**:33 and 34, pp. 2241-2246.

Balakrishnan, P. and Pushpangdan, K., Total Factor-Productivity Growth in Manufacturing Industry. *Economic and Political Weekly*, 1995, March, pp. 462-464.

Balakrishnan, P. and Pushpangdan, K., Total Factor-Productivity Growth in Manufacturing Industry: A Fresh Look. *Economic and Political Weekly*, 1994, **29**.

Bansal, A. Comparison of productivity in the public and private sectors in India: A case study of the fertilizer industry. Mimeo, Delhi School of Economics, Delhi, 1997.

Banerji, A., *Capital intensity and productivity in Indian industry*, Macmillan, Delhi, 1975.

Banerji, A., Production functions for selected Indian industries. *Journal of Development Studies*, 1974, No. 10.

Barua, A., Production function: a survey of the estimates for Indian manufacturing. Discussion Paper No. 66, Development Economics Research Center, University of Warwick, 1985.

Berndt, E.R. and Wood, D.O., Technology, prices and the demand for energy. *Review of Economics and Statistics*, 1975, **57**:3, pp. 259-268.

Berthwal, R.R., The economics of production function, some empirical tests for Indian paper industry. Mimeo.

Bhagwan, M.R., Technology Implication of Structural Adjustment, Case of India. *Economic and Political Weekly*, 1995, **30**:8, pp. M2 - M12.

Bhagwan, M.R., *Technology Transfer in the Third World: Strategies and Prospects*. Zed Books, London, 1990.

Bhagwan, M.R., Capital goods sector in India: past and present trends and future prospects. *Economic and Political Weekly*, 1985, **20**:10, pp. 404-421.

Bhalla, A.S. and Dilmus, D.J., Technological Blending: Frontier Technology in Traditional Economic Sectors. *Journal of Economic Issues*, 1986, **20**:2, pp. 453-462.

Bhalla, A.S., Dilmas D.J. and Stevens, Y. (eds.), *Blending of new and traditional technologies: case studies*. Tycooly International Publishing, Dublin, 1984.

Bhalla, A.S., and Dilmas, D.J., *New Technologies and Development: Experiences in Technology Blending*. Lynne Reinner, Boulder, Colorado, 1988.

Bhardwaj, R.N. Some Aspects of India's Iron and Steel Industry. Ph.D. Thesis (unpublished), Delhi School of Economics, University of Delhi, Delhi, 1994.

Bhanu, V., Liberalisation and performance of cement industry. *Economic and Political Weekly*, 1995, **30**:34, pp. M111-M116.

Bhasin, V.K. and Seth, V.K., Estimation of production function for Indian manufacturing industries. *Indian Journal of Industrial Relations*, 1980, **15**, pp. 335-340.

Bhatia, D.P. Estimates of value added at constant prices in the manufacturing sector: an erroneous methodology. *Economic and Political Weekly*, 1987, **16**, pp. 721-723.

Bhatia, D.P., Misleading growth rates in the manufacturing sector of India. *The Journal of Income and Wealth*, 1990, **12**, pp. 222-25.

Binswanger, H.P., The measurement of technological change biases with many factors of production. *American Economic Review*, 1974, **64**, pp. 964-976.

Brahmananda, P.R., *Productivity in the Indian economy: rising inputs for falling outputs.* Himalaya Publishing House, Bombay, 1982.

CSO, *Wages and productivity in selected industries, 1960 to 1977*. Ministry of Planning, Govt. of India, October 1981.

Caves, D.W., Christensen, L.R. and Diewert, W.E., Multilateral comparisons of output, input and productivity using superlative index numbers. *The Economic Journal*, 1982, **92**, pp. 73-86.

Cement Industry, Annual Review, Specialized Publications, Bombay, 1996.

Chari, S.V., Economics of steel technologies. *Economic and Political Weekly,* 1979, p. M65.

Chatterji, M. (ed.), *Technology Transfer in the Developing Countries*. Macmillan, London,1990.

Crane, D., Technological innovation in developing countries: a review of the literature. *Research Policy*, 1977, **6**:4, pp. 374-395.

Dahlman, C.J. and Westphal, L., The meaning of technological mastery in relation to transfer of technology. In *Annals of the American Academy of Political and Social Science*, 1981, **458,** November, pp. 12-26.

Dahlman, C.J. and Westphal, L., Technological effort in industrial development: an interpretative survey of recent evidence. In Steward, F. and James, J. (eds.), *The Economics of New Technology in Developing Countries*, Frances Pinter, London, pp. 105-137, 1982.

DeGregori, T.K., *A Theory of Technology: Continuity and Change*. Iowa University Press, Ames, 1985.

Denison, E., *The Sources of Economic Growth in the United States and the Alternatives Before Us*. Committee for Economic Development, New York, 1962.

Desai, A.V., *Technology Absorption in Indian Industry*. Wiley Eastern, New Delhi, 1988.

Desai, A.V., Achievements and limitations of India's technological capability. In Fransman and King (eds.), *Asia's New Giant: How the Japanese Economy Works,* The Brooking Institute, Washington D.C, 1984.

Dholakia, R.H. and Dholakia, B.H., Total Factor Productivity Growth in Indian Manufacturing. *Economic and Political Weekly*, 31 December 1994, pp. 3342-3344.

________________ Total Factor Productivity Growth in Indian Industry. *Economic and Political Weekly*, 15 July 1995, pp. 1786-1787.

Diewert, W.E., Exact and superlative index numbers. *Journal of Econometrics*, 1976, **4**.

Diewert, W.E., Capital and Theory of Productivity Measurement. *American Economic Review*, Papers and Proceedings, May 1980.

Divisia, F., L'Indice Monetaire et la Theorie de la Monnaie. Societa anonym du Recueil Sierey, Paris, 1926.

Diwan, R., Returns to scale in Indian industries: a comment. *Indian Economic Journal*, 1968, **15**, pp. 57-82.

Diwan, R. and Gujrati, D., Employment and productivity in Indian industries. *Arthavijnan*, 1968, **10**:10.

Dogra, P.L., Cement Industry in India. Unpublished Ph.D. thesis, Delhi School of Economics, Delhi, 1980.

Dosi, G., *Technical change and Industrial Transformation*, Macmillan, London, 1984.

Dosi, G., Technological paradigms and technological trajectories: A suggested interpretation of the determinants and direction of technical change. *Research Policy*, 1982, **11**:3, pp. 147-162.

Dosi G., Freenam, C., Nelson, R., Silvetag, G., and Soete, L. (eds.), *Technological change and economic theory*. Pintar, London, 1988.

Evenson, R.E. and Westphal, L.E., Technological change and technology strategy. In Behrman, J. and Srinivasan, T.N. (eds.) *Handbook of Development Economics*, 1995, **3B**.

Fabricant, S., Economic Progress and Economic Change. 34th Annual Report of the National Bureau of Economic Research, New York, 1954.

Fransman ,M., *Technology and economic development*. Wheetsheaf, Brighton, 1986.

Fransman, M., *Machinery and economic development*. Macmillan, Houndmills,1986.

Fransman, M. and King, K. (eds.), *Technological capability in the third world*. Macmillan, London, 1984.

Ghosal and Ghose, S.N., A study of productivity in important industries in India. *Productivity Measurement Review*, 1964, **38**.

Ghosh, A. et al., *Indian industrialization, structure and policy issues*. Oxford University Press, Delhi, 1992.

Goel, V.K. and Parameswaran, A., Economics of energy conservation in Indian steel industry. *Man and Development*, 1990, **12**:1, p. 96.

Goldar, B.N., *Productivity growth in Indian industry*. Allied Publishers, New Delhi, 1986.

Goldar, B.N., Productivity and Factor Use Efficiency in Indian Industry. In Ghosh, A. et al. (eds.), *Indian Industrialization and Policy Issues*, 1992.

Goldar, B.N., Import of technology and productivity growth in industry. *Productivity*, 1993, **34**:1, pp. 86-90.

Goldar, B.N., Econometrics of Indian Industry. In Krishna, K.L. (ed.), *Econometric Applications in India*, 1997.

Goldar, B.N. and Mukhopadhyay H., Substitutability among labour, capital and energy in Indian industries, an application of cost price approach. *Journal of Quantitative Economics*, 1991, **7**, pp. 65-78.

Gomulka, S., *Theory of Technological Change and Economic Growth*. Basil Blackwell, 1990.

Griliches, Z., Issues in assessing the contribution of research and development to roductivity growth. *Bell Journal of Economics*, 1979, **10**, pp. 92-116.

Gujarati, Sources of output growth in Indian manufacturing, 1946-58. *Indian Journal of Industrial Relations*, 1967, **3**.

Gupta, G.S., Production function and factor productivity in Indian cement industry. *Indian Journal of Industrial Relations*, 1973, **8**:3, pp. 359-386

Gupta, A., India. In Rughing, F.W. and Brown, C.G. (eds.), *National Policies for Developing High-Tech Industries: International Comparison*, West view, Boulder, Colorado, pp. 89-110, 1986.

Gupta, M., Productivity performance of the public and the private sectors in India: A case study of the fertilizer industry. *Indian Economic Review*, 1982, **27**.

Hashim, B.R. and Dadi, M.M., *Capital output relations in Indian manufacturing (1946-64)*. MS University of Baroda, Baroda, 1973.

Herbert-Copley, B., Technical change in Latin American manufacturing firms: review and synthesis. *World Development*, 1990, **18**:11, pp. 1457-1469.

India, Government of, *Science and Technology Plan 1974-79*. Department of Science and Technology, New Delhi, 1975.

Ito, S., Modifying imported technology by local engineers: hypothesis and case study of India. *Developing Countries*, 1986, **24**:3, pp. 334-348.

Jain, B.K. and Nand, S., Productivity in the Indian Fertiliser Industry. *Fertiliser News*, 1980, pp. 7-18.

James, J. (ed.), *The Technological Behaviour of Public Enterprises in Developing Countries*. London, Routeledge, 1989.

Jha, R., Murty, M.N., Paul, S. and Bhaskara, R.V., An analysis of technological change, factor substitution and economies of scale in manufacturing industries in India. *Applied Economics*, 1993, **25**, pp. 1337-1343.

Jha, R., Murty, M.N. and Paul, S., Technological change, factor substitution and economies of scale in selected manufacturing industries in India. *Journal of Quantitative Economics*, 1991, **7**:1, pp. 165-178.

Jorgenson, D.W. and Griliches, Z., The explanation of productivity change. *Review of Economic Studies*, 1967, **34**, pp. 249-283.

Kalra, G.D. and Radhakrishnan, P.N., *Aluminium industry in India, problems and prospects*. Vol I and II, National Council of Applied Economic Research, New Delhi, 1987.

Kazi, V.A., The Variable Elasticity of Substitution Production Function: A Case Study for Indian Manufacturing Industries. *Oxford Economic Papers*, 1980, **32**, pp.163-175.

Kendrick, J.W., Productivity trends, capital and labour. *Review of Economics and Statistics*, 1957, **39**:3, pp. 248-257.

Kendrick, D., *Productivity Trends in the United States*. Princeton University Press, Princeton, NJ, 1961.

Kendrick, J.W. and Vaccona, B.N. (eds), *New developments in productivity measurement and analysis*. University of Chicago Press, 1980.

Kokrady, A.S., *Energy use in selected Indian industries*. Unpublished Ph.D. thesis, Delhi School of Economics, Delhi, 1992.

Krishna, K.L., Total factor productivity, concepts and measurement. *Productivity*, 1970, **10**:4.

Krishna, K.L., Industrial Growth and Productivity in India. In Brahmanada, P.R. and Panchamukhi, V.R. (eds.), *The Development Process of the Indian Economy*, Himalaya Publishing Home, Bombay, 1987.

Krishna, K.L., Industrial Growth and Diversification. In Kapila, U. (ed.), *Indian Economy Since Independence*, Academic Foundation, Delhi, pp. 538-561, 1995.

Krishna, K.L. (ed.), *Econometric Applications in India*. Oxford University Press, Delhi, 1997.

Kumari, A., Productivity in public sector. *Economic and Political Weekly*, 27 Nov. 1993, pp. M145 - M162.

Lall, S., India's technological capacity: effects of trade, industrial science and technology policies. In Fransman and King, *Technological capability in the Third World*, Macmillian, London, pp. 225-243, 1994.

Lynk, E.L., Factor demand, substitution and biased technical change in Indian manufacturing industries. *Manchester School of Economics and Social Studies*, 1982, **2**, pp. 126-138.

Mahopatra, B.K., The Rate of Technical change in Indian Cement Industry, 1949-64. *Asian Economic Review*, 1970, **12**:3, pp. 297-309.

Majumdar, S.K., Fall and Rise of Productivity in the Indian Industry. *Economic and Political Weekly*, 30 Nov 1996.

Marjit, S. and Singh, N., Technology and Indian industry. In Mookherjee, D. (ed.), *Indian industry, policies and performance*, 1995.

Mehta, B.C. and Madnani, G.M.K., Size, technology and productivity in cement industry in India. *Productivity*, 1973, **14**:3, p. 249.

Mehta, S.S., *Productivity, production function and technical change*. Concept Publishing Co., New Delhi, 1980.

Mehta, S.S., Returns to scale and sources of growth of output in large scale industries. *Indian Journal of Industrial Relations*, 1976, **11**, pp. 339-350.

Mitra, A., Varoudakis, A. and Veganzones, M., State infrastructure and productive performance in Indian manufacturing. Technical Paper, OECD Development Centre, Paris, 1998.

Mohanty, D., Growth and Productivity in Indian manufacturing. *RBI Occasional Papers*, 1992, **13**, pp. 55-80

Mookherjee, D. (ed.), *Indian industry, policies and performance*, Delhi, Oxford University Press, 1995.

Murty, M.N. Interfuel substitution and derived demand for inputs in the manufacturing sector of India. *Journal of Quantitative Economics*, 1986, **2**:1, pp. 119-135.

Murty, V. N. and Sastri, V.K., Production functions for Indian industry, *Econometrica*, 1957, **25**.

Nadiri, M.I., Some approaches to the theory and measurement of total factor productivity, a survey. *Journal of Economic Literature*, 1970, **8**.

Nair, N. K., Productivity ratios in Indian iron and steel industry. *Lokudyog*, 1973, **7**:7, p. 41.

Narasimhan, G.V.L. and Fabrary, M.Z., Relative efficiency of organized industries in India, 1949-58. *Journal of Development Studies*, 1974, **10**, pp. 230-41.

National Productivity Council, Energy Consumption Trends in Glass Industry. *Productivity*, 1993, **34**:2, pp. 356-358.

National Productivity Council, Energy Productivity in Indian Manufacturing Industries, (1973-88). *Productivity*, 1993, **34**:3, pp. 528-534.

National Productivity Council, Energy Productivity in Indian Manufacturing Industries. *Productivity*, 1991, **32**:1, pp. 166-172.

National Productivity Council, Productivity in Indian Cement Industry. *Productivity*, 1991, **32**:1, pp. 141-165.

National Productivity Council, Productivity in Indian Iron and Steel Industry. *Productivity*, 1988, **28**:4, p. 393.

Nebebe, F. and Kira, D., Estimating elasticities in pulp and paper industry, an economic analysis of Canadian regions. *Indian Journal for Quantitative Economics*, 1992, **8**:2, p. 451.

Pal, M. and Datta, M., Productivity trend in the organised manufacturing sector in India: 1970-1988. *The Journal of Income and Wealth*, 1995, **17**, pp. 136-44.

Pant, M., Availability indicators in the iron and steel industry. *Productivity,* 1989, **30**:1, p. 101.

Pant, M., Energy indicators in the iron and steel industry. *Productivity*, 1989, **30**:1, p. 102.

Parhi, M., *Liberalisation, Productivity and R&D: An Inter-Industry Analysis*. M.Phil. Dissertation, University of Delhi, 1997.

Pavitt, K., The objectives of technology policy. *Science and Public Policy*, 1987, **14**, pp. 182-188.

Pearson, R., *The Mexican Cement Industry: Technology, Market Structure and Growth*. IDB/ ECLA/ IDRC/ UNDP working paper No. 11, Buenos Aires, 1977.

Pradhan, G. and Barik, K. Fluctuating Total Factor Productivity in India: Evidence from Selected Polluting Industries. *Economic and Political Weekly*, **33:**9, 28 Feb.1998, pp. M25-M30.

Pradhan, P.C. and Marwah, P.S., Indian steel industry vis-a-vis energy crisis. *Lokudyog*, 1975, **9**:7, p.13

Raghhuraman, V., Reducing energy intensity in selected Indian industrial sub-sectors. Paper presented at conference on *India's Energy consumption in the year 2000*. Petroleum Conservation Research Association & Friedrich Ebert Foundation, New Delhi, 9-10 Nov 1989.

Raghuraman, V., Mahajan, K.C. and Srivastava, P.K., Energy consumption trends in Indian pulp and paper industry. *Productivity*, 1988, **29**:2, pp. 171-180.

Rajkrishna and Mehta, S.S., Productivity trends in large scale industries. *Economic and Political Weekly*, 1968, **3**:43, pp. 1655-1660,

Ramamurthi, R., *State-owned Enterprises in High Technology Industries: Studies in India and Brazil*. Praeger, New York, 1987.

Rao, J.M., Manufacturing Productivity Growth: Method and Measurement. *Economic and Political Weekly*, 1996, **31**:44, pp. 2927-2936.

Rao, J.M., Indices of industrial productivity, growth, disaggregation and interpretation. *Economic and Political Weekly*, 1996, **31**:48, pp. 3177-3188.

Rao, Y.A., *The paper industry in India*. Oxford and IBH Co., New Delhi, 1989.

Rao, P.S., Research and development perspectives in aluminium. *Minerals and Metals*, 1987, **58**:27-29.

Reddy, M.G.K. and Rao, S.V., Functional Distribution in the Large Scale Manufacturing Industry in India. *Artha Vijnana*, **4**, 1962.

Rosenberg, N., *Perspectives on Technology*. Cambridge University Press, Cambridge, 1976.

Rosenberg, N., Science, innovation and economic growth. *Economic Journal*, 1974, **100**, pp. 725-729.

Roy, J., *Demand for energy in Indian industries: a quantitative approach*. Daya Publishing House, Delhi, 1992.

Sachdev, V.S., Energy Consumption in Aluminium Industry. *Minerals and Metals*, 1987, **58:**31-33.

Samarapungavan, S., Productivity and steel industry. *Productivity*, 1983, **24**:3, p. 335.

Sarkar, A.K., Production function for Indian steel industry. *Indian Economic Journal*, 1965, **12**:3, p. 263.

Sastry, D.U., Total factor productivity growth. *Economic and Political Weekly*, 14 January 1995, p. 127.

Sawhney, P.K., Productivity trends in Indian cement industry. *Asian Economic Review*, 1967, **9**:3, pp. 255-272.

Scherer, F.M., Inter-industry Technology Flows and Productivity Growth. *Review of Economics and Statistics*, 1982, **44**.

Schmookler, J., The Changing Efficiency of the American Economy 1869-1938. *Review of Economics and Statistics*, August 1952.

Sinha, J.N. and Sawhney, P.K., *Wages and Productivity in Selected Indian Industries*, Vikas Publications, Delhi, 1970.

Sengupta, R., *Energy modelling in India*. Planning Commission, India, 1995.

Sengupta, R., Technical change in public sector steel industry. *Economic and Political Weekly*, 1984, **19**, p. 206.

Singh, N., Kochak, A. and Malhotra, N.J., Paper and paperboard industry, productivity, structure and related issues. *Productivity*, 1990, **31**: 3, p. 421.

Singhal, L.K., Productivity in Indian steel industry: international comparisons. *Productivity*, 1993, **34**:3, pp. 510-519.

Shukla, M.K., Steel Industry, half-baked decision on new technologies. *Economic and Political Weekly*, 1984, **19**:48, p. 2019.

Solow, R.M., Technical Change and the Aggregate Production Function. *Review of Economics and Statistics*, 1957, **39**:3, pp. 312-320.

Spence, W.R., *Innovation*. Chapman and Hall, London, 1984.

Srivastva, V., *Liberalisation, productivity and competition: A panel study of Indian manufacturing*. Oxford University Press, Delhi, 1996.

Srivastva, S.K., Productivity in paper industry. *Eastern Economist*, May 1966, **20**.

Steward, F. and James, J. (eds.), *The economics of new technology in developing countries*. Pinter, London, 1982.

Subrahmanyam, G., Factor substitution and relative shares in the paper-paper board industry, 1948-63. *Indian Economic Journal*, 1980, **28**:2, p. 77.

Teitel, S., *Industrial and Technological Development*. Johns Hopkins Press, Baltimore, 1993.

Terleckyi, N., *Effects of R&D on Productivity Growth of Industries: An Exploratory Study*. National Planning Association, Washington, D.C., 1974.

Tinbergen, J., *Zur Theorie der langfristigen Wirtschaftsentwicklung*. Weltwirtschaftliches Archiv, May 1942.

UNCTAD, *Fostering technological dynamism: evolution of thought on technological development process and competitiveness: a review of literature*. U.N. Geneva, April 1996.

Vashist, D.C., Substitution possibilities and price sensitivity of energy demand in Indian manufacturing. *Indian Economic Journal*, 1984, **32**, pp. 84-97.

Williams, M. and Laumas, P.S., Economies of scale for various types of manufacturing production technologies in an underdeveloped economy. *Economic Development and Cultural Change*, 1984, **32**, pp. 401-412.

Yeh, Y., Economies of scale for the Indian manufacturing industries. *Indian Economic Journal*, 1996, **14**, pp. 275-291.